Volcanic construction materials in Idaho

R. R. Asher
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VOLCANIC CONSTRUCTION MATERIALS IN IDAHO

by

R. R. Asher

ABSTRACT

Pumice, pumicite, volcanic cinders, perlite and bentonite are the materials discussed in this report. Pumice is the most important in terms of value, but pumicite has the greatest potential for development. Market areas, annual tonnage and unit value of Idaho pumice are decreasing, but over-all U.S. production is increasing. Idaho pumicite deposits are not exploited, but there are several potential applications in pozzolans, ceramics and expanded products. Neither perlite nor bentonite are abundant; they are only locally important. Volcanic cinder deposits are not regarded as having a large potential for commercial development.

Commercial deposits are restricted to southern Idaho, where they occur in sedimentary and volcanic rocks of Cenozoic age. The origin and distribution of these deposits are related to Tertiary and Recent volcanism that has occurred in the vicinity of the Snake River Plains.

The pumice industry is centered around Idaho Falls, and some production comes from Oneida County. There are also commercial deposits in Teton and Blaine counties. Potential pumicite deposits are found throughout southern Idaho along the margins of the Snake River Plains. The largest deposit is in the Goose Creek Basin, Cassia County, where pumicite is found in outcrops up to 400 feet thick, over an area of several hundred square miles. Volcanic cinders are abundant throughout southern Idaho and deposits are extensively exploited by non-commercial agencies for road metal. Only one commercial deposit of perlite, in Oneida County, is known. Bentonite is also relatively insignificant; one fairly pure bentonite deposit occurs in Owyhee County.
INTRODUCTION

MATERIALS INVESTIGATED

Volcanic construction materials are widespread in Idaho and a large variety of material exists. Pumice, pumicite, volcanic cinders, bentonite and perlite are the materials discussed in this report. Basalt, rhyolite, tuff and related rocks are part of the larger stone industry and they are not included, even though they are properly volcanic construction materials.

PURPOSE OF INVESTIGATION

Volcanic construction materials are abundant in Idaho but there has been relatively little development of these resources. This investigation was undertaken to encourage further development by pointing out the usefulness of the products, areas of occurrence, the extent and quality of the raw materials and by indicating favorable areas of exploration for new deposits.

METHODS OF INVESTIGATION

In order to learn as much as possible about the industry, producing areas were visited and interviews were held with operators. Plants utilizing the raw materials were also visited to learn the specifications and desirable features of the raw materials and finished products as well as their uses and market areas.

Many deposits, both developed and undeveloped, were examined during the investigation. The purpose of these examinations was to gain an idea of the geologic setting and the extent and quality of the material in a deposit. Samples were taken from almost every deposit visited; the samples were later examined microscopically and physically and chemical analyses performed on the more promising samples as a further aid in evaluation.

A reconnaissance of many large, favorable-appearing areas was undertaken to determine the potential for the occurrence of volcanic construction materials, to aid in prospecting for favorably situated deposits.

It was not possible to examine in detail each and every deposit of volcanic construction material in the state. Some deposits were intentionally excluded because they were too small or similar deposits were so widespread in the particular area that collection of further data became repetitious. Undoubtedly some deposits were overlooked, because their presence was not known. However, it is thought that the more important deposits, areas of occurrence and the major features of the industry are included.
AREAS INVESTIGATED

The majority of the volcanic construction materials examined are in southern Idaho. The Snake River Plain and bordering areas, both north and south of the Plain, are of special importance in this respect.

In northern Idaho geologic conditions are not favorable to the occurrence of large volumes of volcanic construction materials. Volcanic ash and tuff are found at some places making up part of the Latah Formation of Miocene age. The Latah Formation consists of thin lenses of sediment of limited horizontal extent occurring between basalt flows of slightly different ages. These interbeds mark sites where sediments accumulated during periods of quiescence in extrusive activity. At various times volcanic ash falls mantled the region and some of the ash, mixed with clay and impure, is preserved in the Latah Formation.

In the vicinity of White Bird, in Idaho County, deposits of volcanic ash 10 to 12 feet thick are reported (Kirkham and Johnson, 1929, p. 491). However, most of the deposits are contaminated with sand and silt. More detailed prospecting in the vicinity of White Bird and other areas where the Latah Formation outcrops might reveal deposits of interest, but it is not likely. Discovery of relatively pure ash in the vicinity of Orofino might be rewarding, as a ready market for the material, as a pozzolan, could exist during the construction of Bruce's Eddy dam.
FORMATIONS CONTAINING VOLCANIC CONSTRUCTION MATERIALS IN IDAHO

TERTIARY ROCKS

Volcanic construction materials in Idaho are localized in rocks of Cenozoic age. The areas of occurrence of Tertiary rocks that are important in this respect are shown in Figure 1. Included are the Challis Volcanics, other Tertiary silicic volcanic rocks, the Payette-Idaho Formation, the Salt Lake Formation and the Snake River Volcanics.

The above-named Tertiary rocks consist of volcanic flows, pyroclastics, sediments and tuffaceous sediments. Many of the flow rocks include lenses of interbedded sedimentary material that occur at different stratigraphic horizons. In areas where detailed studies have been made such intercalated beds have been subdivided and mapped as separate units, but over much of the state detailed information is lacking. Names like Payette Formation and Salt Lake Formation have been broadly applied, by some geologists, to these strata that have certain lithologic, stratigraphic, and broad age similarities that vary within wide limits; a similar nomenclature is followed in this report.

A brief discussion of the various units considered important as sources of volcanic construction materials is presented below.

Challis Volcanics

The Challis Volcanics are a widespread assemblage of volcanic rocks, located north of the Snake River Plain in south-central Idaho. Ross (1962, p. 73) proposes that the term Challis Volcanics be restricted to dominantly volcanic strata of early Tertiary age within the part of central Idaho north of the Snake River Plain and south of the westward-flowing segment of the Salmon River (near lat. 45°30'). Tuff and sedimentary beds intercalated with the lava flows are included in the group.

Ross (1961, p. C-179) says that the Challis Volcanics represent the lower part of the Tertiary deposits of south-central Idaho; they may range in age from Eocene into early Miocene. He also remarks that certain rocks west of Carey, near the northern border of the Snake River Plain, are broadly similar to the Challis Volcanics, but they are probably younger and should be excluded from that formation.

Because of the lack of precise information and for convenience, considering the scale of the map in Figure 1, the silicic volcanic rocks in the vicinity of Magic Reservoir and Carey and Picao, in Blaine County, are shown as Challis Volcanics. Some of these silicic rocks are considered to be of Pliocene age by Malde and others (1963); they apply the name Magic Reservoir Rhyolite.
According to Ross (1962, p. 75) certain components of the Challis Volcanics are rather uniform throughout south-central Idaho, although the character and succession of the flows and included strata vary from place to place. These components are, in ascending stratigraphic order, the latite-andesite member, the basalt and related flows, the Germer Tuffaceous Member, and the Yankee Fork Rhyolite. Anderson (1956, 1957, 1961) has studied the Challis Volcanics in detail in the Salmon area and he has shown that local subdivisions within the various units can be recognized. For the purposes of this investigation such detail is not attempted; where possible, the Germer Tuffaceous Member is shown separately on Figure 1.

Among the various components of the Challis Volcanics the Germer Tuffaceous Member is of chief interest as a source of volcanic construction material, and a reconnaissance of its outcrop area was undertaken in connection with this report. Much of this member is composed of pyroclastic material but most of the tuff and associated strata are well indurated and silicified to a dense, hard rock, and are of little interest as a source of volcanic construction material; this material has been used successfully as a building stone, however.

In the vicinity of Salmon a thick succession of loosely indurated tuffaceous sediments occur; these sediments contain thin beds of impure bentonite at places, but no other volcanic construction materials were found in them.

Between Carey and Picabo a series of ash and pumice beds capped by rhyolitic rocks, can be seen. This occurrence probably represents a lens of the Germer Tuffaceous Member capped by the Yankee Fork Rhyolite. Shockley (1957, p. 13) reports the occurrence of late Tertiary ash, with a thickness of 500 feet, in the Leesburg Basin west of Salmon; the ash overlies Tertiary lake beds that are similar to components of the Germer Tuffaceous Member found near Salmon. Shockley postulates a probable Miocene age for this ash. Pumice occurs near Magic Reservoir as a part of the Magic Reservoir Rhyolite of Malde and others (1963).

The localities mentioned above are the only places where volcanic construction materials were found in the Challis Volcanics. Because such materials do occur in this unit, it is shown on the map of Figure 1. In general, the Challis Volcanics are not considered a likely source of volcanic construction materials.

Tertiary silicic volcanic rocks

An extensive series of volcanic rock is shown on Figure 1 as Tertiary silicic volcanics. This unit includes all the silicic volcanic rocks in southern Idaho except the Challis Volcanics, and it is very widespread. Sedimentary and tuffaceous strata are interbedded with these rocks at many localities; wherever possible the interbedded materials are shown separately on Figure 1, either as the Salt Lake Formation or the Fayette-Idaho Formation.
The silicic volcanic rocks have a considerable range in age. The largest part underlies the Snake River Volcanics and thus cannot be younger than Pliocene; the lower part may be as old as Middle Miocene because it is associated with the uppermost horizons of the Challis Volcanics. In Owyhee County the base is interstrati- fied with Columbia River Basalt of Miocene age (Ross and Forrester, 1958, p. 19).

Savage (1961b, p. 39-41) has discussed the Tertiary extrusive rocks of Bonneville County as Early Snake River Basalt, later silicic volcanic rocks and latest basaltic rocks; the latest basaltic rocks consist of the Intermediate Snake River Volcanics and Late Snake River Volcanics. Thus, in Bonneville County, part of the Snake River Volcanics are older than the silicic volcanics.

Mansfield, (1952, p. 59), in his study of the Ammon and Paradise Valley quadrangles in southeastern Idaho, presents evidence that the rhyolitic tuffs near Ammon may be as young as Pleistocene, however Savage (1961b, p. 43) has pointed out that this is based on unreliable evidence.

Malde and Powers (1962, p. 1200-1201), in a study of the Snake River Plain west of Twin Falls, recognize an older sequence of Miocene basalts and rhyolites with interbedded sandstone, shale and altered, water-laid pyroclastics. These rocks of Miocene age, are followed by the Idavada Volcanics, a thick series of silicic flows and welded tuffs of early to middle Pliocene age. The Idavada Volcanics and older Miocene rocks recognized by Malde and Powers are represented by the Tertiary silicic volcanics shown on the map in Figure 1.

The Tertiary silicic volcanics have been broadly referred to as rhyolite, but quartz latite, latite, dacite and andesite, as well as rhyolite are included in this series (Ross and Forrester, 1958, p. 18). Many of the units that have been classified as normal lava flows are actually welded tuffs that resulted from widespread, explosive volcanic activity (Mansfield and Rosa, 1955, p. 308-321).

The source of the great volume of silicic volcanic rocks and associated pyroco- clastics in southern Idaho cannot be accounted for by the number of known central vents and volcanic cones in the region. Rittman (1962, p. 47) has stated that most ignimbrite sheets originate from fissures; welded tuffs and non-welded pyroclastic material may also result from such activity. Fissure eruptions may have been common in southern Idaho, and a large number of volcanic cones would not be expected.

Stearns and others (1938, p. 41) have suggested that the vents from which the silicic lavas issued are now buried by the younger basalt flows of the Snake River Plain. The copious basalt outpourings, in connection with erosion and down-warping of the Snake River Plain, could bury a cone of considerable size.

Stearns and others (1938, p. 42) also suggest the possibility that the numerous intrusions in mountainous regions bordering the Snake River Plain represent volcanic
feeders and that the evidence of a surface connection has been destroyed by erosion.

Pumice, pumicite and locally perlite are important construction materials associated with the silicic volcanic rocks. The pumice and ash deposits localized in the Idaho Formation, in the Salt Lake Formation and in undifferentiated interbeds between flows and welded tuff sheets of the silicic volcanics had an origin in common with these silicic volcanic rocks. Thus, the Tertiary silicic volcanics are important in connection with volcanic construction materials in southern Idaho. Individual deposits are discussed in a later part of this report.

**Payette-Idaho Formations**

The extensive areas in southwestern Idaho shown on the map in Figure 1 as the Payette-Idaho Formations include the Payette Formation and the Idaho Formation. In southwestern Idaho the Idaho Formation makes the bulk of this unit.

Kirkham (1931, p. 232) desired to restrict the Payette Formation to sedimentary rocks that generally occur interbedded with the Columbia River Basalt, commonly about 600 feet below the top of the basalt unit. As pointed out by Ross and Forrester (1958, p. 17) this restriction has much to commend it in those areas where Kirkham worked; however, there is much local variation in the stratigraphic position of the sedimentary rocks associated with the Columbia River Basalt and it is difficult to distinguish these from similar but younger rocks nearby. Savage (1961a, p. 16) in his discussion of the Payette Formation in Gem and Payette counties, remarks that the Payette Formation, composed of clay, silt, silty ash, arkosic sand and thin coaly layers, is difficult to distinguish from the younger Idaho Formation.

According to Ross and Forrester (1958, p. 17), the term Idaho Formation is applied to those Cenozoic sedimentary rocks in and near the western part of the Snake River Plain that have broad lithologic and genetic resemblances to the Payette Formation, but are younger. The Idaho Formation is interbedded with Snake River Basalt and overlies the silicic volcanic rocks. In places where detailed work has been done, local names have been applied to strata of the Idaho Formation. The Hagerman Lake Beds of Stearns and others (1938, p. 52-56) appear to be continuous with the Idaho Formation (Ross and Forrester, 1958, p. 17).

The silicic volcanics that lie under the Snake River Volcanics contain, in places, many intercalated sedimentary beds which locally include tuffaceous material. According to Ross and Forrester (1958, p. 17), these sedimentary beds are closely related to the Payette Formation. Such intercalated tuffaceous beds are very well exposed in southern Cassia County.

On the State Geologic Map by Ross and Forrester (1947) the Payette Formation is shown west of 114° West Longitude and the Salt Lake Formation is shown east of this Meridian. However, they say (1958, p. 16), that this separation is somewhat arbitrary as it is based on current usage; strata in the two assemblages are nearly equivalent
to each other at some localities.

Savage (1958, p. 24; 1961a, p. 16) reports that the Payette Formation is not extensively exposed in Ada, Canyon, Payette and Gem counties. Most of the silty, sandy, and tuffaceous beds occurring in these counties belong with the Idaho Formation.

In a study of the western Snake River Plain, Malde and Powers (1962, p. 1201-1212) have recognized the Idaho Group and have subdivided the group into seven formations, ranging in age from lower Pliocene to middle Pleistocene. The Idaho Group of Malde and Powers is closely equivalent to the Idaho Formation. The Payette Formation is regarded as Miocene (Ross and Forrester, 1958, p. 16). Thus, the unit shown on the map in Figure 1 as Payette-Idaho Formation ranges in age from Miocene to middle Pleistocene.

The Payette and Idaho Formations consist of clay, silt, silty ash, ash, arkosic sand and thin lignitic layers of fluviatile and lacustrine origin. Volcanic ash is much more abundant than pumice in southwestern Idaho and at places the ash attains a considerable thickness. The ash must have accumulated from ash showers prevailing during eruption of the silicic volcanic rocks. Much of the ash is water-laid, indicating that much of it must have fallen into lakes or sluggish streams following eruption. Some of the ash has been eroded and re-deposited since its original deposition.

Abundant reserves of volcanic ash are present in the Payette and Idaho Formations and these formations represent the most important source of this commodity in Idaho. Individual deposits are discussed in a later part of this report.

Salt Lake Formation

The Salt Lake Formation shown on the map in Figure 1 includes all the sedimentary deposits of Tertiary age in and near the eastern part of the Snake River Plain, except the Wasatch Formation, which is not shown.

Mansfield (1952, p. 46) considers the Salt Lake Formation to be of Pliocene-Pleistocene age; according to Ross and Forrester (1958, p. 18), it is considered to be Pliocene by the U. S. Geological Survey.

The Salt Lake Formation is composed of conglomerate, white marl or limestone, calcareous clay, sandstone, grit and pyroclastic material (Mansfield, 1952, p. 45). Rhyolitic material, largely welded tuff, and basalt are intercalated at several horizons; where possible these are shown separately on the map in Figure 1.

Near Ammon, in Bonneville County, the Salt Lake Formation contains a great deal of pumiceous material and a substantial pumice industry has developed in this
area. The Salt Lake Formation is the most important source of pumice in Idaho.

**Snake River Volcanics**

The Snake River Volcanics underlie most of the Snake River Plain and occur in neighboring areas. This unit extends south and west across Idaho from Fremont County on the east into Oregon and Nevada on the south and west covering an area in excess of 10,000 square miles, and includes basaltic lava flows, pyroclastics, and interbedded sediments and tuffaceous sediments.

According to Ross and Forrester (1958, p. 20), the Snake River Volcanics are Pliocene to Recent in age; the greater part is Pleistocene. Areas of geologically recent flows are shown separately on the map in Figure 1.

In areas where detailed studies have been made, local names have been applied to individual flows and clastic interbeds. Malde and Powers (1962, p. 1212-1217) prefer the name Snake River Group for these rocks in southwestern Idaho; the various flows and interbedded sediments have been given formational names. Stearns and others (1938, p. 56-88), in their study of the Snake River Plain, also subdivided the components into various formational units.

The importance of the Snake River Volcanics, in connection with volcanic construction materials, is the abundance of associated cinders. Cinder cones and associated volcanic features are widespread on and near the Snake River Plain.

Water-laid accumulations of cinders can be found in Ada and Canyon counties associated with recent sediments. These cinders were derived from the Snake River pyroclastics.

Individual areas and occurrences are discussed in the section of this report dealing with cinders.
PUMICE

INTRODUCTION

The principal use of pumice in the western United States is for lightweight aggregate. Almost the entire production of Idaho pumice is used in the manufacture of building blocks. Pumice is also used, when very finely ground, as a pozzolanic material. Pozzolans are admixtures in concrete mixes that are used mainly in large construction projects such as dams; their use results in decreased cement costs and other advantages. Besides the major use of pumice as a construction material, it is also used in minor amounts as an abrasive, a cleansing and polishing material, a filler in paints, a carrier for insecticides, loose-fill insulation, a filter medium, and as a soil conditioner.

LIGHTWEIGHT AGGREGATE

Development of lightweight aggregate industry

The use of lightweight concrete began in the United States, in the last part of the 19th century. Building design changed from thick, heavy, load-bearing walls to a supporting structural steel framework covered by a thin shell. Walls, floors, and ceilings were made in the nature of partitions; strength was not of primary importance. Because thin walls transmit heat and sound, insulating properties became important features of lightweight aggregate used in building construction (Moyer, 1942, p. 2).

Lightweight masonry spread from use in commercial buildings to residential and farm construction. Lightness in weight is not nearly as essential in residential home construction as in tall, multistory buildings or other large structures, but it is an advantage (Moyer, 1942, p. 2). Lightweight aggregates were also found desirable in the production of large-size, pre-cast masonry units, and complete lines of building blocks, bricks, roof and floor tiles and slabs appeared on the construction materials market (Moyer, 1942, p. 2).

In addition to their use in poured concrete masonry and pre-cast units, lightweight aggregates are used in applied finishes such as stucco, and acoustical plaster. The products are light in weight, provide good insulation and they are fire proof.

Advantages and disadvantages of lightweight concrete and lightweight masonry units

Lightweight aggregate imparts in varying degrees, certain characteristics to monolithic concrete, which makes its use desirable. A high strength-for-weight ratio allows savings in structural steel and foundation size, the concrete is fire resistant, it has good insulating properties and it is shock resistant. Walls made with lightweight concrete show very little condensed moisture. Nails may be driven into the concrete and it can be sawed (Clippinger, 1946, p. 14–19).
There are several disadvantages associated with the use of lightweight concrete including greater cost (30 to 50 percent), need for more care in placing, greater porosity, and more drying shrinkage (U. S. Bur. Reclamation, 1955, p. 359).

Pre-cast pumice concrete construction units include building blocks, structural roofs, non-structural roofs, load-bearing walls, partition walls, acoustic panels, floor slabs, and roof tiles. Building block production accounts for the largest consumption of pumice aggregate.

The use of lightweight blocks introduces savings by decreasing foundation cost; handling, manufacturing, hauling and installation costs are also less in comparison to standard concrete blocks. A standard pumice block 8"x8"x16" has a unit wall surface area of 128 square inches. A standard 4"x12" ordinary concrete block has a unit wall surface area of only 48 square inches. Therefore, only one-third as much mortar is required to build a wall of pumice blocks. Because pumice blocks have a larger surface area, and weigh only 25 to 30 pounds, less time and labor are involved in construction than with ordinary concrete blocks. Pumice aggregates impart a certain amount of elasticity to the masonry units. There is little breakage during handling because of the elasticity and light weight.

The use of pumice fines in the mortar used for bonding pumice blocks together makes a homogeneous structure with little tendency for cracking, because the thermal expansion properties of the blocks and mortar are equal. Pumice block structures are highly fire resistant and the use of pumice mortar makes them even more so.

Desirable features of lightweight aggregate

In order to justify the use of lightweight aggregate for making concrete, a worthwhile saving in weight must result because lightweight aggregate is in general, more costly than normal aggregate (Kiersch, 1955b, p. 54). The saving in weight is important in large building design but the concrete made using lightweight aggregate must also be strong enough to meet specifications. A high strength-to-weight ratio is, therefore, extremely important in lightweight aggregate. In addition to strength and weight considerations, the concrete mix must be workable, the aggregate must have low absorption, be well graded, contain no reactive chemical impurities and have good insulation properties.

PUMICE AS LIGHTWEIGHT AGGREGATE

Features of suitable pumice aggregate

Some pumice demonstrates many of the characteristics of good lightweight aggregate, but not all pumice is suitable. The pumice must consist of strong, clean fragments or granules. Grading of the aggregate is very important for the production of high quality concrete. Size distribution should range from very fine sand to about 3/4" in diameter (Clippinger and Gay, 1947, p. 19). Because pit-run material seldom possesses
the necessary grading, careful screening, crushing and blending are required. Poorly graded aggregate produces an inferior, low strength concrete (Clippinger and Gay, 1947, p. 37).

When a standard mix design is used for concrete, the amount of each size of pumice aggregate should be calculated on the percentage by volume rather than by weight. The bulk specific gravity of pumice sand becomes progressively higher as the individual particle size diminishes; if the recommended particle sizes are added on a weight basis, a deficiency in the finer size ranges will result (Clippinger and Gay, 1947, p. 20).

The vesicles in the pumice should be small and evenly distributed. Excessively frothy pumice is too weak (Williamson and Burgin, 1960, p. 7). If a large number of vesicles are interconnected, the pumice will be too porous for high-quality aggregate. Excessive absorption and drying shrinkage results. The material should be cellular but not porous.

The U. S. Bureau of Reclamation (1955, p. 51) reports that certain acidic glassy rocks (including pumice) are reactive with cement alkalis released during hydration. It is recommended that pumice aggregate be used with low alkali cements. Opal, chalcedony, tridymite, cristobalite, zeolite and heulandite, are known to be reactive with cement alkalis. Good pumice must be free of these reactive materials to avoid expansion and cracking in the concrete.

Impurities such as silt, clay, mica, coal, humus and other organic matter should not be present in pumice aggregate. Considerable care must be taken in mining operations to insure clean stripping of soil and overburden (Clippinger and Gay, 1947, p. 18).

Features of pumice concrete

Pumice aggregate produces concrete of intermediate strength. Absorption is low-to-medium, unit weight is 50 to 60 percent that of ordinary concrete. Fair insulating properties, moderate to excessive shrinkage, fair-to-good workability, fair-to-good nailability and fair-to-excellent sawability may be expected (Cole and Zetterstrom, 1954, p. 9). A serious problem encountered with pumice concrete is excessive drying shrinkage. There are several ways of partially overcoming this difficulty such as replacing part of the pumice fines with natural sand, heat treatment of the aggregate, use of a minimum water-cement ratio in the mix, careful curing, vacuum processing and vibration. The use of admixtures, such as entrained air or pozzolan, has been found effective in controlling drying shrinkage and generally improving the quality of pumice concrete (U. S. Bur. Reclamation, 1955, p. 362).

Pre-cast units are molded into forms; the water-cement ratio is kept as low as possible. Normally the amount of water used does not exceed the minimum necessary
for hydration. Because of the low water-cement ratio of the mix, the degree of compaction is never as great as that obtained with plastic mixes (Chesterman, 1956, p. 111). The compaction is accomplished by force, either by vibration, hydraulic or air compression (Carothers, 1946, p. 11). The strength of pre-cast pumice units is not as great as the strength of concrete from plastic mixes because it is not as well compacted.

Steam curing of pumice concrete blocks reduces shrinkage and absorption (Clipping and Gay, 1947, p. 34). The autoclave process of curing, by use of steam and pressure, reduces shrinkage, reduces absorption and increases the strength of the pre-cast units. The quality of pumice concrete blocks depends on the quality and grading of the pumice, the type of block machine used and the quality control practiced by the producer.

Specifications for lightweight concrete and concrete products

Pumice is used as aggregate in monolithic structures, in pre-cast concrete products and in applied finishes. The following strength-weight specifications are given by the A S T M (1960) for lightweight aggregates for structural concrete, in which the primary consideration is lightness in weight and compressive strength.

<table>
<thead>
<tr>
<th>Average 28-day compressive strength, min. psi (cement test cylinders)</th>
<th>Average unit weight, max. lb. per cu. ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>4000</td>
<td>115</td>
</tr>
<tr>
<td>3000</td>
<td>110</td>
</tr>
<tr>
<td>2000</td>
<td>105</td>
</tr>
</tbody>
</table>

Intermediate values may be established by interpolation.

Pumice aggregate is not readily suitable for use in transit mix operations because of the high water requirement and extensive mixing time involved (W. J. Hoelzinger, personal communication, Nov. 1962).

The insulating factor of a material, usually termed the "K" factor, is expressed as the number of British Thermal Units (B. T. U.'s) per square foot per hour, per inch thickness, per degree Fahrenheit temperature gradient between two sides of a wall or block. The lower the K factor the better the insulation. In general, the K factor increases with the density of the material and would be much higher for conventional concrete than for pumice concrete.
The A S T M (1956) has established specifications for lightweight aggregates for insulating concrete. The specifications cover aggregates intended for use in concrete not exposed to weather, in which the prime consideration is the thermal insulating property of the concrete. The thermal insulating properties of concrete made from the lightweight aggregate shall conform to the following limits:

<table>
<thead>
<tr>
<th>Max. average 28-day oven-dry unit weight, lb. per cu. ft.</th>
<th>Max. average thermal conductivity, B T U in. per hr. sq. ft. deg. Fahr. (&quot;K&quot; factor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1.50</td>
</tr>
<tr>
<td>90</td>
<td>3.00</td>
</tr>
</tbody>
</table>

The A S T M has established specifications for hollow load-bearing concrete masonry units (1959a), hollow non-load-bearing concrete masonry units (1959b), and solid load-bearing concrete masonry units (1959c). The specifications cover compressive strength, water absorption and moisture content. The various specifications follow:

### Hollow load-bearing concrete masonry units

<table>
<thead>
<tr>
<th>Min. face shell thickness, in.</th>
<th>Compressive strength, min. psi (average gross area)</th>
<th>Water absorption, max., lb. per cu. ft.</th>
<th>Moisture content, max., percentage of total absorption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average of 5 units</td>
<td>Individual units</td>
<td>Average of 5 units</td>
</tr>
<tr>
<td>1 1/4 or over:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade A</td>
<td>1000</td>
<td>800</td>
<td>15</td>
</tr>
<tr>
<td>Grade B</td>
<td>700</td>
<td>600</td>
<td>...</td>
</tr>
<tr>
<td>Under 1 1/4, Over 3/4</td>
<td>1000</td>
<td>800</td>
<td>15</td>
</tr>
</tbody>
</table>

### Hollow non-load-bearing concrete masonry units

<table>
<thead>
<tr>
<th>Compressive strength, min. psi (average gross area)</th>
<th>Moisture content, max., percent of total absorption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average of 5 units</td>
<td>Individual units</td>
</tr>
<tr>
<td>350</td>
<td>300</td>
</tr>
</tbody>
</table>
Solid load-bearing concrete masonry units

<table>
<thead>
<tr>
<th>Grade</th>
<th>Average of 5 units</th>
<th>Individual unit</th>
<th>Moisture content, max., percentage of total absorption</th>
</tr>
</thead>
<tbody>
<tr>
<td>A...</td>
<td>1800</td>
<td>1600</td>
<td>15</td>
</tr>
<tr>
<td>B...</td>
<td>1200</td>
<td>1000</td>
<td>15</td>
</tr>
</tbody>
</table>

Most Idaho pumice block producers state that their products have a compressive strength of 1000 psi, or over. Although the strength requirement for Class A hollow load-bearing masonry units is met, the blocks may not meet the specifications for water absorption and moisture content. Blocks that have not been properly cured before delivery to the job site shrink excessively and cracks develop in the structure. Poor quality control has damaged the reputation of pumice products in some areas with resulting loss of markets.

Most lightweight concrete products, including pumice, demonstrate more absorption than ordinary concrete. Excessive absorption can be overcome by applying a cement-base paint to the exposed surfaces in the structure.

Grading requirements and unit weight requirements for lightweight aggregate for concrete masonry units are established by the A S T M (1959d).

**Grading**

<table>
<thead>
<tr>
<th>Percentage (by weight) passing sieves having square openings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size designation</td>
</tr>
<tr>
<td>Fine aggregate:</td>
</tr>
<tr>
<td>No. 4 to 0</td>
</tr>
<tr>
<td>Coarse aggregate:</td>
</tr>
<tr>
<td>1/2&quot; to No. 4</td>
</tr>
<tr>
<td>3/8&quot; to No. 8</td>
</tr>
<tr>
<td>Combined fine and coarse aggregate:</td>
</tr>
<tr>
<td>1/2&quot; to 0</td>
</tr>
</tbody>
</table>
Unit weight

<table>
<thead>
<tr>
<th>Size designation</th>
<th>Dry loose weight, max. lb. per cu. ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine aggregate</td>
<td>70</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>55</td>
</tr>
<tr>
<td>Combined fine and coarse aggregate</td>
<td>65</td>
</tr>
</tbody>
</table>

**Materials competing with pumice as lightweight aggregate**

Pumice competes with expanded clays and shales, expanded perlite and vermiculite, slag, industrial cinders, volcanic cinders and diatomite as lightweight aggregate. Artificially expanded clay and shale is preferred by many users of lightweight concrete aggregate. The crushing strength of expanded clay and shale is greater than the crushing strength of pumice, yet the unit weight does not exceed specifications. In addition, the properties of artificially expanded products can be closely controlled to meet any desired requirement of grain size and vesicular structure.

The principal use of pumice is in concrete blocks. Volcanic cinders are also used extensively as aggregate for concrete blocks and they are preferred in some areas. Cinder blocks are somewhat heavier than pumice blocks but this difficulty is partially offset by greater strength.

In comparison to other lightweight products, pumice is hampered by lack of research into new uses and adequate publicity. An organization similar to the Perlite Institute, Vermiculite Association or the Expanded Clay and Shale Association doesn’t exist at this writing for pumice producers and consumers. In 1948 an organization called the Pumice Producers Association was formed. The initial aims of this association were organized research programs, standardization of pumice for use as concrete aggregate and a program of national advertising (Metcalf, 1948, p. 108). In 1955 the formation of the Pumice Institute was announced; its aims were to unify the efforts of pumice producers to develop technical data and information for architects, structural engineers and builders on the use of pumice construction (Otis and Marks, 1955, p. 937). Apparently neither of these organizations was successful as they are not active at the present time.
OTHER USES OF PUMICE

Pozzolan

Pumicite and tuff are better suited for pozzolan production than is pumice. Materials for pozzolans must be extremely fine; most specifications require that more than 85 percent of the material pass a 325-mesh screen. Pumicite and tuff occur in their natural state as fine material; pumice occurs as larger granules and fragments. If an established and secure market could be developed for pozzolans, existing pumice operations would be in a favorable position, however, because existing facilities could readily be adapted to production of pulverized material. (Pozzolans are discussed further in the section of this report dealing with pumicite).

The use of pozzolans as a partial replacement for the cement in block manufacture is worth investigation. Finely ground pumice is an excellent pozzolan; pumice blocks made with a suitable pozzolan should have less shrinkage, increased strength, less absorption, a lower unit production cost and less weight. If a superior lightweight unit could be made using pozzolan it would help to establish more secure markets for pumice products.

Applied finishes, mortar and insulation

Pumice aggregate for interior plaster requires very careful screening; precisely graded aggregate is necessary. Air entraining agents may be introduced into the aggregate to aid workability, insulation, sound control and to reduce weight. The air-entraining agent introduces dead air cells into the plaster which decreases the K factor (Chesiterman, 1956, p. 113). Pumice aggregate produces an acoustical, insulating, lightweight, fire-resistant plaster. Stucco finishes for outside walls may also be made from pumice aggregates; stucco possesses features similar to interior plaster. Expanded perlite or expanded vermiculite are preferred materials for plaster aggregate. By close control of the raw materials and expanding operations, the physical properties of the expanded product are uniform.

Masonry mortar made from pumice is used in much the same manner as ordinary sand mortar. It provides the same insulation as pumice masonry blocks. Pumice mortar has the same thermal coefficient of expansion that pumice masonry units have, and when used in conjunction with these units, uniform expansion and contraction in response to temperature changes are attained.

Pumice is used as loose-fill for heat and sound insulation. Grading must be precise. Loose-fill insulation is a comparatively minor use for pumice, however, as expanded perlite, and expanded vermiculite are preferred insulating materials; they dominate the market.
Minor uses

Prior to World War II industrial uses as abrasive and polishing compounds accounted for the largest consumption of pumice (Williamson and Burgin, 1960, p. 5). Since that time industrial uses have declined and now constitute a very minor use. Increased transportation costs and the manufacture of artificial abrasive materials have caused the decline in sales of pumice for industrial uses.

Pumice intended for use as an abrasive must meet very rigid specifications. The vesicles must be small as compared to the particle size of the material used, or if in a fine powder, the shards must be able to bring sharp edges to bear on the surfaces. Grains of foreign material and crystals and fragments of authigenic minerals greatly detract from the quality of the product. The best material occurs in lumps from which at least hand-sized blocks can be cut (Williamson and Burgin, 1960, p. 11).

Pumice has been used as a soil conditioner with very good results. Air and moisture are held in the pores of the pumice rendering the soil porous. Very little physical or chemical breakdown of the pumice takes place over long periods of time (Clippinger and Gay, 1947, p. 44).

Some experimentation has been done in the field of hydroponics using pumice as a seed bed to which chemicals are added. Results have been very encouraging (Clippinger and Gay, 1947, p. 45).

Other minor uses of pumice are insecticide carriers, oil well slurries, brick manufacture, filter mediums, fillers in non-slip paints and absorbents.

MINING METHODS AND ECONOMIC CONSIDERATIONS

Mining and milling

Almost all pumice is produced from open-pit mines. In most operations blasting is not required, as the deposits are only partially consolidated. At some places the material is excavated by power shovels, draglines or scoop loaders and loaded into trucks for haulage to the processing mill at the railroad. At other places, where the deposit is near a railroad siding, the mill is located at the mine and the material is excavated by dragline or bulldozer and is moved directly to storage piles near loading chutes or conveyor systems before milling.

A pumice mill consists of a scalping screen to remove soil and other impurities as well as oversize lumps. Ball and hammer mills are employed to reduce the oversize. The material is screened and blended to produce the desired size gradations (Otis, 1960a, p. 681).
Economic considerations

The major markets for lightweight aggregate and lightweight concrete products are near population centers. A pumice deposit must be favorably located in regard to transportation facilities and markets. Pumice is a relatively low-priced commodity and an operation cannot withstand the cost of long haulage to railroad loading points. Railroad freight charges are an appreciable part of a producer's costs and long distances to markets cause many deposits to be uneconomic even though the pumice is otherwise suitable.

According to information received from the Union Pacific Railroad (R. A. Anderson, personal communication, March, 1964) there is no set policy or basis used to arrive at costs per ton mile for shipping volcanic construction materials. Many factors, such as value of the commodity, whether an occasional or regular volume of movement, susceptibility to damage and claims, competitive consuming market conditions, heavy versus light loading, extent of branch line hauls and other considerations are used in establishing the shipping rate. Consequently, rates vary considerably. A geographic limitation is imposed on the extent of marketing areas for a given deposit governed by freight costs.

Other considerations bearing on the economics of a deposit are its extent and thickness, amount of overburden, physical characteristics and purity.

Almost the entire production of pumice in Idaho is used for making building blocks. Although expanded clay and shale are preferred for monolithic concrete projects, this material is not widely used in the building block industry. Closer quality control, use of pozzolans and the discovery of pumice deposits closer to market areas would encourage wider use of pumice and pumice products.

ORIGIN AND OTHER FEATURES OF PUMICE

Terminology and origin

Pumice and other materials formed by explosive volcanic activity are called pyroclastic rocks. The term pyroclastic refers to detrital volcanic materials that have been explosively or aerally ejected from a volcanic vent; it is also applied to the class of rocks made up of these materials (A.G.I. 1957, p. 235). Bombs and blocks are fragments larger than 32 mm across; fragments between 4 mm and 32 mm are called lapilli; those smaller than 4 mm are called ashes or pumicite. The rocks resulting from the compaction and cementation of these ejecta are called agglomerates if they are composed of bombs, volcanic breccias if composed chiefly of blocks. Indurated ashes are called tuffs; those rich in lapilli are called lapilli tuffs (Williams and others, 1955, p. 149).

Pumice is pyroclastic ejecta characterized by a markedly cellular texture, called pumiceous texture. Pumice can be defined as accumulations of highly cellular,
lightweight, glassy lapilli and bombs or the rocks made up of these materials. The term generally refers to ejecta of acid to intermediate composition, similar to the composition of rhyolite or andesite, resulting from explosive volcanic activity. Basic pumices have been recognized but they are not nearly so common as acidic varieties (Chesterman, 1956, p. 7). The term pumice is also used to indicate the frothy material found in the upper parts of some lava flows (Longwell and others, 1939, p. 279).

The cellular structure of pumice develops only when a particular set of circumstances prevails at the time of accumulation and eruption of a magma. Factors affecting the formation of pumice are the confining pressure, the gas content, and the viscosity of the magma. Viscosity is affected by chemical composition and temperature.

Volcanic eruptions are caused by unequal pressures. The pressure change is greatest at the moment the molten material is released from mechanical pressure in a volcanic conduit. When the conduit is unrestricted the magma is expelled freely and the pressure drop is uniform. So long as the magma remains sufficiently fluid, gases expand into bubbles and percolate upward to escape. When the magma freezes the bubbles are trapped and must escape by seepage or by fracturing of the bubble walls. The scoriaceous or pumiceous surface of some lava flows is formed by this mechanism.

Pumiceous material is discharged from an erupting volcano when the confining pressure is removed quickly so as to cause a sudden change in pressure, as by mechanical rupture of a plug blocking a conduit. The lava column is suddenly unloaded, dissolved gases and disseminated bubbles in the magma are mobilized, bubbles increase in number and size, causing frothing of the magma, and the density of the lava column decreases. The drop in specific gravity further increases the imbalance of pressure; the frothed magma is expelled into the cooling atmosphere, and the cellular structure characteristic of pumice develops in the volcanic debris. Following this phase, the pressure change is more gradual, the gases have more time to adjust to the new conditions and the pyroclastic material is replaced by heavier lava (Williamson and Burgin, 1960, p. 12).

The viscosity of the magma, at the time of expulsion, must be high enough to retain a large amount of gas, but not too great to keep the gas from collecting and expanding; the viscosity must also hinder the escape of gases from ejected particles until the bubble walls have solidified in order for pumice to form (Rittman, 1962, p. 75). As pointed out by Williamson and Burgin (1960, p. 12), vesicles are formed by detention and retention of gases rather than by the escape of gases. When the gases escape readily the vesicles disappear with them for the walls of the bubbles must be supported at least until they have frozen.

Acid to intermediate magmas generally have a higher gas content, are more viscous and have a higher melting point than basic magmas. Therefore, conditions
favoring the formation of pumice are more likely to develop in acid magmas.

Pyroclastic ejecta discharged from a volcano may be blown high above the vent and be cooled or cold before they land. Some material may be discharged as flowing avalanches that move rapidly downslope and spread over large areas. Mixtures of incandescent spray, droplets, larger clots of foaming magma and incandescent blocks are held in a mobile suspension dispersed in hot expanding gases. The suspension may be discharged from swarms of fissures, the flanks of volcanic domes, or over a crater rim. These glowing avalanches may attain considerable thickness and remain hot for a long time, particularly in their central parts. Shards of glass, pumiceous lapilli and bombs are flattened while still hot and under heavy overburden, and they become firmly annealed. The resulting rock is described as a welded tuff.

According to Rittman (1962, p. 47) many rhyolite deposits are not lava flows at all but represent welded glowing cloud deposits. Many of these deposits pass marginally into less coherent and finally into completely incoherent, glassy ashes. Several investigators have pointed out that much of the so-called rhyolite of southern Idaho are in reality welded tuffs (Youngquist and Haegle, 1956, p. 17; Mansfield and Ross, 1935, p. 308-309). According to Rittman (1962, p. 47):

"In the majority of occurrences of such ignimbrite sheets, it can be incontestably demonstrated that the overflowing glowing cloud, which gave rise to them, erupted from a fissure. They therefore represent purely explosive fissure eruptions on a grand scale."

If such is the case in southern Idaho, where welded tuffs are abundant, the general lack of acidic, extinct volcanic cones, is explained. The widespread deposits of pumice and pumice found in southern Idaho probably originated mainly from fissure eruptions as well.

Gases are given off from extruded lava flows as well as being emitted from volcanic vents. As lavas cool and harden gases are given off for long periods of time. The upper parts of some lava flows may become highly vesiculated and frothy, particularly acidic flows. The frothed material topping these flows is also referred to as pumice. If the lava was still moving at the time the vesicles were formed, they will be almond shaped (Longwell and others, 1939, p. 279).

Several factors influence the distribution of the particles expelled during an explosive eruption. Parts of the frothed magma are ejected more violently than others and the fragments are more finely divided. These fragments of pumice are swept upward and outward by escaping gases and are deposited farther from the volcanic vent than the larger fragments. Size distribution is also influenced by the density of the ejected material and changes in wind velocity during an eruption. Gradations from pumice to pumice might be expected as a deposit is followed toward its source.
Fragments rich in crystals or lithic fragments are generally deposited closer to the source than glassy particles (Williams and others, 1955, p. 151).

Deposits of pyroclastic ejecta, such as pumice, can be classified according to their mode of deposition. They may be subaerial, subaqueous, or reworked. Subaerial deposits are composed of ejecta that were deposited on land following their eruption; subaqueous deposits are composed of particles that were deposited in water following eruption and reworked deposits represent eroded and redeposited material derived from the other types (Chesterman, 1956, p. 7, p. 24). Most of the known pumice deposits of Idaho are either subaqueous or reworked, but all types exist.

**Physical features and chemical composition**

When pumice is examined with a microscope, under low magnification, it appears to be a coherent mass of fibers with a silky luster. The fibers are interwound and parallel. The material has a white streak, and an irregular cleavage. It is brittle to pulverulent. When it is pulverized and examined with a microscope it resembles broken glass. The specific gravity of pumice is 2.5 but the bulk specific gravity varies, depending on the percent of vesicles present in the material. When enough vesicles are present, the bulk specific gravity is less than one and the material will float on water. Pumice is generally light colored. White is the most common color but it may be gray, buff or brownish yellow.

The composition of pumice ranges from rhyolite to basalt. The more siliceous varieties are by far the most common and the most important commercially. A typical commercial pumice sample has the following chemical analysis (Otis, 1960, p. 660):

<table>
<thead>
<tr>
<th>SiO₂</th>
<th>70.6</th>
<th>FeO</th>
<th>2.0</th>
<th>Na₂O</th>
<th>3.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>14.0</td>
<td>MgO</td>
<td>0.6</td>
<td>K₂O</td>
<td>3.3</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>1.3</td>
<td>CaO</td>
<td>1.7</td>
<td>H₂O</td>
<td>2.9</td>
</tr>
</tbody>
</table>

In a pumice deposit, phenocrysts and crystal fragments are nearly always present, in some they are abundant. Therefore, the chemical composition of pumice varies, depending on the amount and kind of contained phenocrysts and crystal fragments. Plagioclase, hornblende, quartz, hypersthene, biotite, magnetite, and augite are the most common non-glassy constituents. It has been noted that finely divided pumiceous material is more siliceous than coarser material. It is thought that the crystalline fraction drops out during air transportation of the finer material. When pumice is mechanically crushed, the crystalline particles are free and may be separated (Williamson and Burgin, 1960, p. 11).

Pyroclastic deposits, particularly fine-grained ones, are readily altered because of their high porosity, large surface area of the fragments, and the inherently unstable character of their glassy fragments (Williams and others, 1955, p. 156).
In time the glass becomes clouded with minute crystalline material and eventually it becomes cryptocrystalline. This process is called devitrification. It takes place whether altering agencies such as surface weathering or circulating groundwaters are active or not (Williamson and Burgin, 1960, p. 12).

Weathering agencies and circulating groundwaters cause rapid alteration of pyroclastic material. Opal and clay of the montmorillonite group are common alteration products of pumice. Bentonite is a variety of clay formed by the alteration of acidic pyroclastic material (Williams and others, 1955, p. 157).

Many deposits of acid and intermediate tuffs are extensively silicified, owing to the deposition of quartz, chalcedony or opal from groundwater enriched in silica during devitrification of the glass. Petrified wood is found among such silicified deposits. Commerially valuable deposits of pumice older than Tertiary are rare because of rapid devitrification and alteration.

THE PUMICE INDUSTRY IN IDAHO

Production and value

The following tables and graphs (Figs. 2 to 4) show the production records of pumice, pumicite and volcanic cinders in Idaho since 1946, with a comparison to the United States as a whole. The basic data used in making up the charts and graphs, were collected from the U. S. Bureau of Mines Minerals Yearbooks for 1945 through 1962.

From 1945 through 1952, the U. S. Bureau of Mines reported pumice and pumicite production only; since 1953, volcanic cinders have been included as part of the total production. The figures pertaining to the production of cinders can be separated from the figures pertaining to the production of pumice and pumicite for the entire United States, but the production figures are reported as a grand total for the individual states and no separation of data can be made. Accordingly the data shown for Idaho includes pumice and pumicite up to 1953, and pumice, pumicite and volcanic cinders since 1953.

Pumice operations in Idaho are operated on a commercial basis by private firms; all but two of the many cinder deposits in the state are operated by noncommercial groups such as county and state road maintenance organizations. Consequently, it is difficult to place a value other than production cost on the cinders consumed. In addition, cinder production is sporadic and accurate records of tonnage are not known.

In view of the difficulties involved in collecting and analyzing the data pertaining to the production of pumice, pumicite and volcanic cinders, the information presented below should be considered as an indication of the general trend only.
Figure 2 Graphs comparing U.S. and Idaho production of pumice, pumicite and volcanic cinders.
Figure 3—Graphs Comparing Value Of U.S. And Idaho Production Of Pumice, Pumicite And Volcanic Cinders With Percent Of U.S. Value Produced By Idaho.
Figure 4—Unit Value Of Pumice, Pumicite And Volcanic Cinders Produced In U.S. And In Idaho.
Figure 2 shows the tonnage of pumice, pumicite and volcanic cinders produced in Idaho and in the United States from 1946 to 1962. The percentage of the United States total produced by Idaho is also shown to demonstrate the sharp decline in the relative importance of Idaho production. In general, while over-all United States production has increased markedly, Idaho production has decreased, according to available information.

The total reported production in the United States between 1952 and 1953 increased some 126 percent, because in 1953 volcanic cinders were included as part of the pumice production record. In Idaho a slight decline was noted between the 1952 and 1953 production. By inspection of Figure 2 it is clear that the general increase in total production in the entire United States is because of the increased consumption of cinders while pumice production, on the average, has been relatively constant. In Idaho, total production has declined sharply, especially since 1958.

There is no means of comparing Idaho pumice production directly against Idaho cinder production. It is known that a quantity of cinders is used each year in highway construction and maintenance, and as railroad ballast. Evidently these cinders are not being reported to the U. S. Bureau of Mines. Thus, neither the total Idaho tonnage nor the percent of the total United States production produced by Idaho have declined as sharply as indicated since 1952. However, discussions with Idaho pumice producers indicate that the actual production of pumice alone has been declining steadily over the past several years.

Figure 3 shows the total annual value of pumice, pumicite and volcanic cinders produced in the United States, and in Idaho. The same general trends are indicated as in the graph of total production (Fig. 2).

Figure 4 shows the unit value of pumice, pumicite and volcanic cinders in the United States, and in Idaho. This figure indicates that the unit value of Idaho pumice is far below that of the average United States price, and that Idaho pumice is worth even less than the average price of cinders in the United States. Since most of the reported Idaho production is pumice and includes only a minor quantity of cinders, the figure is a fairly reliable indication of the unit value of Idaho's pumice.

The average unit value, as determined from data presented by the U. S. Bureau of Mines, is most likely a weighted average of the value of crude and processed material. Much of the pumice produced in Idaho is sold as pit-run material while at other localities the pumice is processed before it is marketed. Consequently, the average value of Idaho pumice would be somewhat lower than the United States average. Sufficient data are not available for a direct comparison between the value of crude Idaho pumice and the average value of crude pumice produced in the entire United States.
The average value of pumice and pumicite used for concrete aggregate and admixtures is shown for the United States from 1958 through 1962 on Figure 4. Because practically all Idaho pumice is used as aggregate the graph shows that the average value of Idaho pumice for this purpose is about $1.50 less than the average United States value.

Because of the lack of vital information concerning pumice production the figures or unit value are not precise but they are indicative.

It would appear that one of the primary reasons for the decline of the pumice industry in Idaho is the low unit value commanded by the material in comparison to the United States average. Until the value of the Idaho pumice is somewhat nearer the national average, the industry will not expand, because of lack of incentive.

The reason for the lower unit value of Idaho pumice is not clear. Idaho pumice is of acceptable quality; the low unit value may reflect unfavorable freight rates, that, if added to the unit price, tend to make Idaho pumice uncompetitive. Competition from artificially expanded lightweight aggregate, such as expanded clay and shale, may also play a part in keeping the price down. However, such competition should also be reflected on a national basis. There seems to be some correlation between uses and price. In 1962, 44 percent of the total United States output of pumice, pumicite and volcanic cinders was used as concrete admixtures and aggregates at $3.04 per ton; 30 percent for railroad ballast at 0.89 cents per ton, and 21 percent for road construction at $1.67 per ton. These three uses accounted for 95 percent of the output in 1962, amounting to 2,180,000 short tons. If all the volcanic cinder produced, 738,000 short tons, can be assumed to have been consumed by these three uses, 87 percent of the pumice and pumicite produced or 448,000 short tons, would be required to make a total of 2,180,000 short tons. The remaining 13 percent of the pumice and pumicite must have been used for such purposes as cleaning and scouring compounds and other abrasive uses at $34.48 per ton; insulation at $9.94 per ton and other unclassified uses at $2.63 per ton. Therefore, the value of the pumice produced would be increased by these specialized uses. Since all of the Idaho production goes into block manufacture and markets in more specialized fields are lacking, the value of Idaho pumice would be somewhat below the national average.

In order for the Idaho pumice industry to expand successfully, the value of the product must increase to a point nearer the national average; the best way to increase the value is through the development of new markets by development of specialized products commanding higher prices. Research into new uses for pumice and the development of new markets is essential.

According to information in the U. S. Bureau of Mines Minerals Yearbooks (1948-1962) research by private individuals and organizations over the past several years has developed new processes and uses for pumice; many of the processes and products are patented. Included are: methods of producing low-cost structural clay
blocks using pumice aggregate; products containing pumice for use as decorative and water-proofing compounds on cement blocks, wood, clay or other structural materials; methods of making porous cellular products with pumice or obsidian from mixtures of the ground volcanic rock mixed with sodium nitrate and hydroxide; the material is fired at 1300° to 2000° F. until the mixture melts and foams. Methods of producing improved insulation products have been developed. More uses for pumice in the construction market are being developed such as manufacturing gypsum board using pumice as lightweight aggregate and coating the pumice particles with asphalt or other compounds so as to make the aggregate waterproof. Production of pre-mixed, coated, lightweight aggregate and cement that can be bagged and stored has been successful; the use of pumice in sound-deadening tile has been attempted. The manufacture of hydraulic cement using pumice as a major constituent and methods of purifying air by using treated pumice are other possibilities. These developments indicate that there are many uses for pumice, and new markets and products can be developed through research and experimentation. Markets that have been lost to other products must be replaced by new markets.

The compilation shown in Table 1 is the data from which the graphs were constructed. This chart and the graphs (Figs. 2 to 4) show the history of the pumice industry in Idaho and no further remarks on the history of the industry are needed.

Mining laws applicable to pumice

The provisions of Public Law 167 are discussed by Walenta (1961). This law states that: (1) the Secretary of Agriculture and the Secretary of the Interior, in respect to the federal lands under their direction, may sell and dispose of the surface resources, including such mineral resources as common varieties of sand, stone, gravel, pumice, pumicite, cinders and clay; (2) the Act also provides that henceforth no mining claim may be located by reason of a discovery of common varieties of sand, stone, gravel, pumice, pumicite or cinders. This does not, however, prevent the inclusion of such minerals within a mining location when such location was based upon the discovery of some other valuable mineral. This section has no application to valid, existing mining locations made before the passage of the Act on July 23, 1955 (Walenta, 1961, p. 5).

Section 5 of Public Law 167 provides that any head of a federal department or agency which has the responsibility for administering the surface resources on any land belonging to the United States, may institute proceedings to test the validity of any unpatented mining claim located prior to the passage of the Act on July 23, 1955 (Walenta, 1961, p. 10).

Walenta (1961, p. 15) says that, in his opinion mining locations based upon a discovery of common varieties of sand, gravel, stone, pumice or cinders will be declared invalid under Section 5 of Public Law 167, or under the quiet title procedures
<table>
<thead>
<tr>
<th>Year</th>
<th>Commodity</th>
<th>ENTIRE U. S.</th>
<th>IDAHO</th>
<th>Percent of U. S. total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Tonnage</td>
<td>Value</td>
<td>Tonnage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(short tons)</td>
<td>(dollars)</td>
<td>(short tons)</td>
</tr>
<tr>
<td></td>
<td></td>
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<td>(per ton)</td>
<td>Unit value</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td>1945</td>
<td>Pumice, Pumicite</td>
<td>157,011</td>
<td>1,051,307</td>
<td>$6.70</td>
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<tr>
<td>1946</td>
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<td>319,883</td>
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<td>1947</td>
<td>Pumice, Pumicite</td>
<td>442,552</td>
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<td>1948</td>
<td>Pumice, Pumicite</td>
<td>716,742</td>
<td>2,369,822</td>
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<tr>
<td>1949</td>
<td>Pumice, Pumicite</td>
<td>738,000</td>
<td>2,298,300</td>
<td>3.90</td>
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<tr>
<td>1950</td>
<td>Pumice, Pumicite</td>
<td>719,356</td>
<td>2,661,052</td>
<td>3.70</td>
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<td>1951</td>
<td>Pumice, Pumicite</td>
<td>749,942</td>
<td>2,752,907</td>
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<td>1952</td>
<td>Pumice, Pumicite</td>
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<td>2,266,981</td>
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<td>2,096,040</td>
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<tr>
<td></td>
<td>Volcanic Cinders</td>
<td>612,000</td>
<td>430,000</td>
<td>0.70</td>
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<tr>
<td>1954</td>
<td>Pumice, Pumicite</td>
<td>957,341</td>
<td>2,498,894</td>
<td>2.61</td>
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<tr>
<td></td>
<td>Volcanic Cinders</td>
<td>690,056</td>
<td>475,424</td>
<td>0.69</td>
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<tr>
<td>1955</td>
<td>Pumice, Pumicite</td>
<td>842,962</td>
<td>2,422,900</td>
<td>2.90</td>
</tr>
<tr>
<td></td>
<td>Volcanic Cinders</td>
<td>961,526</td>
<td>926,816</td>
<td>0.96</td>
</tr>
<tr>
<td>1956</td>
<td>Pumice, Pumicite</td>
<td>887,553</td>
<td>3,222,704</td>
<td>3.63</td>
</tr>
<tr>
<td></td>
<td>Volcanic Cinders</td>
<td>584,661</td>
<td>1,527,053</td>
<td>2.57</td>
</tr>
<tr>
<td>1957</td>
<td>Pumice, Pumicite</td>
<td>1,054,594</td>
<td>3,090,677</td>
<td>2.93</td>
</tr>
<tr>
<td></td>
<td>Volcanic Cinders</td>
<td>772,384</td>
<td>1,536,535</td>
<td>1.99</td>
</tr>
<tr>
<td>1958</td>
<td>Pumice, Pumicite</td>
<td>925,000</td>
<td>3,091,000</td>
<td>3.34</td>
</tr>
<tr>
<td></td>
<td>Volcanic Cinders</td>
<td>1,048,000</td>
<td>2,196,000</td>
<td>2.10</td>
</tr>
<tr>
<td>1959</td>
<td>Pumice, Pumicite</td>
<td>784,000</td>
<td>3,267,000</td>
<td>4.17</td>
</tr>
<tr>
<td></td>
<td>Volcanic Cinders</td>
<td>1,492,000</td>
<td>2,596,000</td>
<td>1.74</td>
</tr>
<tr>
<td>1960</td>
<td>Pumice, Pumicite</td>
<td>602,000</td>
<td>2,757,000</td>
<td>4.60</td>
</tr>
<tr>
<td></td>
<td>Volcanic Cinders</td>
<td>1,610,000</td>
<td>2,802,000</td>
<td>1.74</td>
</tr>
<tr>
<td>1961</td>
<td>Pumice, Pumicite</td>
<td>936,000</td>
<td>3,103,000</td>
<td>4.49</td>
</tr>
<tr>
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<td>Volcanic Cinders</td>
<td>1,527,000</td>
<td>2,596,000</td>
<td>1.70</td>
</tr>
<tr>
<td>1962</td>
<td>Pumice, Pumicite</td>
<td>592,000</td>
<td>3,157,000</td>
<td>5.22</td>
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<tr>
<td></td>
<td>Volcanic Cinders</td>
<td>1,738,000</td>
<td>3,095,000</td>
<td>1.78</td>
</tr>
</tbody>
</table>
of another law - Section 7 of Public Law 585. In the case of pumice, pumicite and cinders, the proof of actual rather than potential value of the particular deposit in question is necessary, since without a convenient market the deposit could not be exploited at a profit no matter how extensive it might be.

Pumice and related materials on land belonging to the State of Idaho are subject to the mining laws of Idaho. A discovery may be made on such materials and a lease obtained from the State Land Board in Boise.

PUMICE DEPOSITS IN IDAHO

Pumice -- Owyhee County -- Sec. 33, T2N, R4W

Pumice, overlying volcanic ash, sand and silt beds of the Idaho Formation, occurs about 5 miles south of Marsing in Sec. 32 and 33, T2N, R4W. The occurrence is located about two miles east of U. S. Highway 95 on an abandoned practice bombing range. The pumice occurs at the head of a broad, southeast-trending draw; a dry stream course follows the western side of the draw. The draw joins the main valley of Squaw Creek to the south. On the east a mesa-like butte with near vertical sides and a flat top borders the draw (Fig. 5). The mesa is composed of light-colored sands and gravels of the Idaho Formation. The top of the mesa is about 150 feet above the floor of the valley. On the west the draw slopes steeply upward for about 120 feet to a broad, level, plateau-like surface. The western slope is composed of slightly indurated fine sands and silts. It is probable that a fault follows the base of the mesa on the east.

Some bulldozer work has been done on this deposit and the cuts expose the thickness of the pumice and the underlying beds. A layer of pumice about 10 feet thick caps an underlying series of fine silt, clay, volcanic ash and impure diatomite. A traverse from the pumice outcrop, west, through a vertical distance of 82 feet to the bottom of the dry stream bed, shows a series of silt and clay beds ranging in thickness from 2 to 10 feet with several thin beds of volcanic ash included in the series (Table 2). The ash beds are from one to three feet thick. Diatoms are present in most of the silt beds.

Several periods of volcanic activity are represented by this occurrence. The ash and pumice must have been deposited by streams in local ponds and lakes. Periods of quiescence, or less intense volcanic activity are represented by the beds of silt and diatomite.

The pumice occurs as irregular patches capping several knobs and other elevated areas on the floor of the wide draw. The pumiceous material covers an area about 200 feet by 400 feet in the vicinity of the bulldozer cuts. Several smaller outcrops of pumice can be seen in the draw farther southeast.
<table>
<thead>
<tr>
<th>Layer Description</th>
<th>Depth (Ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumice, finely vesicular, breaks into aggregate lumps 4 to 6 inches across;</td>
<td>10</td>
</tr>
<tr>
<td>composed of fine pumice particles. Glass, crystalline quartz, feldspar laths and</td>
<td></td>
</tr>
<tr>
<td>cryptocrystalline material are present; quartz fills vesicles, makes up 10 to</td>
<td></td>
</tr>
<tr>
<td>15 percent of a specimen.</td>
<td></td>
</tr>
<tr>
<td>Clay with volcanic glass shards, minor alteration of glass.</td>
<td>3</td>
</tr>
<tr>
<td>Mixed diatomite and clay; clay predominates.</td>
<td>20</td>
</tr>
<tr>
<td>Mixed clay, diatomite, volcanic glass.</td>
<td>2</td>
</tr>
<tr>
<td>Volcanic ash, gray, fairly pure, powdery.</td>
<td></td>
</tr>
<tr>
<td>Mixed clay, diatomite, volcanic glass; includes a 6-inch bed of fairly pure</td>
<td>10</td>
</tr>
<tr>
<td>volcanic ash.</td>
<td></td>
</tr>
<tr>
<td>Diatomite, fairly pure; diatom tests very small; minor clay aggregates.</td>
<td>2</td>
</tr>
<tr>
<td>Diatomite, impure; very fine texture; white, powdery on weathered surface, fresh</td>
<td>12</td>
</tr>
<tr>
<td>pieces break into rectangular blocks about 6 inches by 4 inches;              composed</td>
<td></td>
</tr>
<tr>
<td>of diatom tests, clay aggregates; minor volcanic ash.</td>
<td></td>
</tr>
<tr>
<td>Clay with shards of volcanic glass, minor diatoms.</td>
<td>10</td>
</tr>
<tr>
<td>Volcanic ash, gray, very fine, powdery, pure; shards are clear and broken into</td>
<td>2</td>
</tr>
<tr>
<td>angular fragments.</td>
<td></td>
</tr>
<tr>
<td>Tuff; indurated mass of dark, angular shards of volcanic glass with minor clear</td>
<td>2</td>
</tr>
<tr>
<td>glass shards; glass particles coated with clay.</td>
<td></td>
</tr>
<tr>
<td>Mixed volcanic ash, diatomite and clay.</td>
<td>2</td>
</tr>
<tr>
<td>Volcanic ash, extremely fine, light gray, powdery.</td>
<td>1</td>
</tr>
<tr>
<td>Soil, light colored, silty in bottom of draw; slakes rapidly in water.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>82</td>
</tr>
</tbody>
</table>
Figure 5— Map Of Pumice Occurrence, Sec. 33, T2N, R4W, Owyhee County.
The beds along the line of the traverse strike about N65W, and dip about 10SW. One small, vertical fault was observed in the series. The displacement along the fault is only 2 to 3 feet; it strikes N10E.

The pumice at this locality has very fine vesicles; it is composed of small fragments that are well indurated into a lapilli tuff. The tuff breaks into pieces of agglomerated particles 4 inches to 6 inches across. The limited thickness, irregular distribution of outcrops and the small size of individual pumice particles would hinder commercial development of this deposit.

Pumice -- Twin Falls County -- Sec. 6, T13S, R17E

A bulldozer cut exposes pumice on the Ora Jones farm about 4 miles east and 2 miles south of Hollister. The deposit is in the W1/2 of Sec. 6, T13S, R17E (Fig. 6).

The area of occurrence is on the western flank of the Cassia Mountains. The pumice is associated with other pyroclastic rocks, mostly welded tuffs, and silicic flow rocks. The deposit is near the contact between Snake River Basalt of Quaternary age on the west and silicic volcanic rocks of Miocene to Pliocene age on the east.

A wide bulldozer cut exposes the pumice on the fairly gentle west slope of a north-trending ridge. The east slope of this ridge is much steeper than the west; it drops sharply down to the floor of an enclosed basin. Except where bulldozer cuts have exposed the underlying material, little can be seen. Sagebrush, soil and gravel mantle the slopes and basin floor.

North of the pumice exposed in the bulldozer cuts a small knoll rises above the ridge level. The knoll is capped by rhyolite or welded tuff. Several small bulldozer cuts on the west slope of the knoll expose dark, glassy obsidian, with a pitchy luster. The obsidian shows well developed perlitic structure, and a distinct banding resembling flow structures. The perlitic material expands slightly on heating but the zone is too thin to be of commercial interest.

Underlying the obsidian 6 feet of dark volcanic ash can be seen; it appears to be bedded. This ash is composed of small, flattened, clear fluted glass shards. The dark color may have been imparted to the volcanic ash because of baking by the overlying flow. Below the dark volcanic ash, light gray, slightly compacted, fine ash occurs. The ash is composed of very fine, broken, flattened shards of glass and a few minor mica flakes. The total thickness of the ash and obsidian was not determined because neither the upper or lower contact could be seen.

In the bulldozer cut pumice is exposed over an area about 550 feet long by 100 feet wide. The exposed thickness is 50 feet, the total thickness is not known. The pumice underlies the volcanic ash described above. Under the microscope the pumice
particles appear to be fibrous, compact masses of glass shards. The material is easily crushed. Obsidian grains are abundant in the pumice and a few quartz grains can be seen. The pumice is white to light gray in color. Bedding is not obvious in the deposit and no sand or silt layers were observed.

A search east of the ridge along the rim of the enclosed basin failed to reveal other pumice exposures and none were seen north or south of the deposit along the west slope of the ridge. It seems that the pumice exposed is a local lens, however, further prospecting along the slopes of the ridge, north and south of the bulldozer cut, followed by trenching, might reveal other occurrences. According to Jones (oral communication, July, 1963), pumice is widespread in the vicinity; it has been encountered at depth in water-well drilling operations at many places in the area but surface outcrops are rare.

The presence of perlitic obsidian at the base of the capping rhyolite or welded tuff flow overlying the pumice is indicative of quick-cooling and damp conditions. The pumice and ash probably filled a local pond or lake which was later covered by a flow. However, there is a lack of bedding and non-volcanic sedimentary material in the deposit that indicates rapid accumulation of friable pyroclastic debris. The existence of further pumice deposits in the area is likely. It is doubtful if perlite in commercial quantities is available, however.

The pumice particles are small and easily crushed between the fingers. Lack of coarse material and lack of particle strength would probably make this material unsuitable for lightweight concrete aggregate. If finely ground, it might find use as a pozzolan. Other possible uses would include small local demands such as road metal and flooring for canals, stockyards, and the like.

**Pumice - Power County - approximately Sec. 27, T9S, R30E**

Staley (1950, p. 6) comments on this occurrence. He remarks that he had visited the deposit several years earlier and was favorably impressed, even though only a limited amount of work had been done at the time. He goes on to say that now (1950) the exposure has become covered by hillwash and it is difficult to find. Staley regards the occurrence as promising and expresses little doubt that a deposit can be found with only a moderate amount of trenching.

This locality was visited but little could be seen. Information concerning the location of the deposit and its ownership was obtained at the Ellason Ranch located about 6 miles north of Rockland on Rock Creek at about the center of the south boundary of Sec. 14, T9S, R30E. The pumice is found about 3 miles northwest of Rockland in Sec. 27, T9S, R30E (Fig. 45).

The Ellason Brothers own the deposit. The occurrence is in a steep draw, the sides and bottom of which are completely covered by alluvium. A minor amount of development work was done in the past, but, as indicated by Staley, the exposures are now obliterated by hillwash.
Figure 6 — Location Map Of Pumice Deposit, Sec. 6, T13S, R17E, Twin Falls County.
In addition to the occurrence examined by Staley at the above locality, pumice is reportedly exposed at several other places in Rockland Valley. Supposedly, one such deposit can be seen about 6 miles west of Rockland on the southwest side of Table Mountain. A thorough search of that area was made in addition to a reconnaissance of a large area surrounding Rockland, but no other pumice was found.

Volcanic ash resources are widespread in Rockland Valley; occurrences at some places are 150 feet thick. Several ash outcrops were visited and samples taken; they are discussed further in the pumicite section of this report.

The deposits in Rockland Valley are associated with the Salt Lake Formation that is widely exposed in the vicinity (Fig. 1).

**Pumice - Oneida County - approximately Sec. 8, T12S, R35E**

The M. J. Hess Construction Company of Malad operates a pumice pit located some 20 miles north of Malad City. The pit is on Wrights Creek, on the west side of the road that follows this stream, approximately in Sec. 8, T12S, R35E (Fig. 7). The road is paved to a point about a mile south of the pit; the interval from the end of the pavement to the mine is surfaced with pumice. The pumice is a highly satisfactory road aggregate.

The pumice in the deposit is fairly hard and indurated; it is light gray to white in color. A ripper is used to loosen the material; it breaks up into lumps 8 to 12 inches across. The deposit is being mined by a series of benches along the hillside above Wrights Creek.

The pumice occurs in a series of alternating coarse and fine beds. It appears to be waterlaid but there is a lack of nonpumiceous material such as sand, silt and clay in the deposit. Individual particles in the coarser beds are from one inch to two inches across. The finer material ranges between fine and coarse sand in size. The bedding dips south, up to 10 degrees, but the amount of inclination is variable. Soil overburden covers the deposit and extends away from the pit in all directions. Indications are that the deposit extends north; small, isolated occurrences of pumice can be found at several places between the pit and the Oneida Perlite Corporation mine 5 miles farther north on Wrights Creek. A waterlaid mixture of pumice and perlite can be seen overlying the perlite near the mine. The evidence indicates that pumice reserves are substantial in this area.

The pumice is probably part of the Salt Lake Formation. This formation is extensively exposed north and west of this locality (Fig. 1) and careful prospecting would undoubtedly lead to the discovery of other pumice deposits of commercial interest.
The pumice pit is about 1,000 feet long north-south and 500 feet wide. Pumice has been extracted through a vertical distance of 75 to 100 feet. The loosened material is pushed with a bulldozer to a jaw crusher located on the floor of the pit at road level; the crusher breaks up the aggregate lumps into individual particles and reduces the larger particles to 3/4 inch. The pumice is screened and graded into 5 size fractions ranging from 3/4 inch to fines. Much of the pumice is sold as blended material, in many different blends, depending on the desire of the customer (M. J. Hess, personal communication, October, 1963).

Utah markets in the vicinity of Ogden and Salt Lake City are the principal consumers of the product from the Malad pumice operation but other markets are becoming available, such as those in the Boise area. Lightweight aggregate for building blocks is the chief use of the pumice. The blended product sells for $2.50 per ton (M. J. Hess, personal communication, October, 1963).

A sample of the pit-run material yielded the screen analysis shown by the histogram in Figure 9. The analysis shows that approximately 75 percent of the material is in the size range from 0.75-inch to 0.05-inch. A unit weight of 50 pounds per cubic foot was determined for the sample.

Table 3 shows the results of a chemical analysis of a sample from the pit. Because this pumice has been demonstrated to be satisfactory aggregate the analysis can be used as an indication of the composition of pumice that is suitable for aggregate.

**TABLE 3. Chemical Analysis of Pumice, Sec. 8, T12S, R35E, Oneida County (A. M. Lothe, Analyst).**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>Fe₂O₃</td>
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<tr>
<td>Al₂O₃</td>
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<td>SiO₂</td>
<td>65.2</td>
</tr>
<tr>
<td>CaO</td>
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</tr>
<tr>
<td>MgO</td>
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</tr>
<tr>
<td>Na₂O</td>
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<tr>
<td>K₂O</td>
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</tr>
<tr>
<td>Loss on ignition</td>
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</tr>
<tr>
<td></td>
<td>99.3</td>
</tr>
</tbody>
</table>

Pumice - Bonneville County - Idaho Falls Area

The chief pumice-producing area in Idaho is near Idaho Falls in Bonneville County. Pumice is mined from open pits in an area about 6 miles east of Ammon in the foothills on the west flank of the Blackfoot Mountains. Beds of pumice and ash are associated with the Salt Lake Formation of Pliocene age in this vicinity.
Figure 7—Location Map Of Pumice Deposit, Sec.8, T12S, R35E, Oneida County.
The accompanying map (Fig. 8) shows the distribution of the Salt Lake Formation in Bonneville County, as well as areas of Tertiary silicic volcanic rocks, mostly welded tuffs. This map is taken from Savage (1961b). Over much of the area, welded tuffs lie directly on ash and pumice of the Salt Lake Formation and they effectively conceal the underlying material. Mansfield (1952, p. 45) notes that fine, wind-blown dust covers much of the area; it is particularly abundant in Tps. 1 and 2N, R39E. A good deal of the pumice produced has come from these townships. Mansfield mapped this wind-blown dust as part of the Salt Lake Formation but mentions (p. 45) that it may be younger. Savage (1961b, p. 34) states that loess deposits of Quaternary age are widespread. The effect of the dust is to mantle the area and conceal the underlying pumice deposits.

The Salt Lake Formation in the vicinity is made up of conglomerate, white marl or limestone, calcareous clay, sandstone, grit and pyroclastic material. The sedimentary materials are sparse but the pyroclastic material is fairly abundant. The pyroclastics consist of ash and pumice that are well bedded and water-laid (Mansfield, 1952, p. 45). The Salt Lake Formation, including the pumice deposits, was laid down on a highly irregular eroded surface. Thicknesses range from very thin to several hundred feet (Mansfield, 1952, p. 46).

Rhyolitic rocks overlie much of the Salt Lake Formation. These rocks are principally welded tuffs, also pyroclastic in character. Bedded ash and pumice commonly underlie the welded tuffs; the ash and pumice are baked near the contacts. The underlying ash is not coextensive with the welded tuff; in some places the ash was eroded before the tuff was deposited and the tuff rests directly on older rocks. The thickness of the overlying tuff is variable; it is commonly about 25 feet (Mansfield, 1952, p. 54).

Mansfield (1952, p. 54) mentions the following localities where nonwelded rhyolitic tuff, that is, ash and pumice, are exceptionally well exposed: Secs. 16, 17, 20, 21, 28, 32, and 33, T2N, R39E; Sec. 5, T1N, R39E; Sec. 20, T1N, R40E, and Sec. 16, T1S, R40E. During the present investigation several of these exposures were visited as well as others. Descriptions of the occurrences visited follow. Savage (1961b, p. 58) notes the occurrence of pumice along Call Dugway above Meadow Creek Valley; this occurrence was also visited.

- Meadow Creek – Call Dugway – Sec. 1, T2N, R40E

At this locality pumice outcrops can be seen for about three-quarters of a mile along the road (Call Dugway) leading down into Meadow Creek Valley (Locality 1, Fig. 8). Approximately 250 feet above the valley floor, pumice beds capped by about 20 feet of vesicular, pink rhyolitic rocks, occur interbedded with silt beds containing pumice particles, and black, sandy, pumiceous beds. The beds are lenticular and pinch out in short distances, thicknesses of the various beds are irregular; the material appears to be cross-bedded (Fig. 14).
About a quarter of a mile farther south, about 200 feet above the valley floor, the pumice outcrop is fairly massive. There is a lack of coarse material in the pumice and the particles are soft and easily crushed; many of the fragments have a clay coating. Cross-bedding is also evident in this outcrop, but there is less silt and other nonvolcanic material than nearer the top of the exposure farther north. Similar material is exposed in the road bank for another half mile to a point about 100 feet above the stream valley. Below the pumice beds, in the road cut, black, sandy beds and fine, light-colored sand, with some ash, occur to the level of Meadow Creek.

Impure, altered pumice is exposed through a vertical distance of about 150 feet at this locality.

Sec. 23, 26, T2N, R39E

About 5 miles southeast of Iona, near the section boundary between Sec. 23 and 26, T2N, R39E, grayish-white pumice occurs in a road cut on the east side of a small, north-trending gully (Locality 2, Fig. 8). Fine soil and rhyolite overlie the exposure. The pumice appears to be of acceptable quality but it contains an abundance of fine material. Screening would be required to separate the finer particles. It is exposed for about 200 feet horizontally through 15 to 20 feet vertically. The pumice particles occur in a matrix of volcanic ash.

A histogram showing the size distribution of the material from this deposit is given in Figure 10. The unit weight of the sample was determined as 61 pounds per cubic foot.

Sec. 17, T2N, R39E

About a quarter of a mile west of Highway FAS 6723 in Sec. 17, T2N, R39E pumice, in a matrix of ash, is exposed in a small cut on a hillside at the margin of a wheatfield (Locality 3, Fig. 8). Soil overlies the exposure. There are several small pits in the vicinity that expose pumice for about a quarter of a mile around the hillside through a vertical distance of about 10 feet. The total thickness is not known, but it is likely that further exploration would expose a greater volume of pumiceous material. The pumice is similar in appearance to that mined near Ammon, but a screen analysis of a sample shows that the pumice is somewhat finer. A histogram showing the screen analysis is presented in Figure 11. The unit weight, as determined from the sample, is 53 pounds per cubic foot.

N.E. Cor. Sec. 14, T2N, R39E

About 5 miles east, and a mile south of Iona a pit exposes pumice in the N.E. corner of Sec. 14, T2N, R39E (Locality 5, Fig. 8). The pit is about 25 feet long with a face about 20 feet high. Approximately 10 feet of pumice is exposed; it is overlain
Figure 8 - Map Showing Outcrop Area of Salt Lake Formation and Tertiary Silicic Volcanic Rocks, Idaho Falls and Vicinity, Bonneville County.
by gray to black sand and silt. The bedding dips about 20°E with a marked steepening near the east end of the pit. The pumice exposed is rather fine; the pumice fragments are in a matrix of volcanic glass.

A screen analysis gives the distribution shown in Figure 12. The analysis shows that about 40 percent of the material is in the pumice size range with most of the pumice as fine particles. The unit weight of the material is 48 pounds per cubic foot.

SE1/4 Sec. 19, T2N, R39E

At this locality, in the SE1/4 Sec. 19, T2N, R39E (Locality 5, Fig. 8), Mansfield (1952, p. 52) describes a measured section through a welded tuff series of the capping rhyolitic rocks. The measured section is as follows:

Welded tuff – SE1/4 Sec. 19, T2N, R39E

<table>
<thead>
<tr>
<th>Description</th>
<th>FT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuff, highly vesicular, strongly resembling rhyolitic flow</td>
<td>10.0</td>
</tr>
<tr>
<td>Tuff, resembling stony rhyolite flow, fairly free from vesicles</td>
<td>1.5</td>
</tr>
<tr>
<td>Tuff, glassy, black, like obsidian; spherulitic, with spherules 2 1/2 to 3 in. in diameter</td>
<td>2.0</td>
</tr>
<tr>
<td>Tuff, glassy, black, perlitic</td>
<td>1.0</td>
</tr>
<tr>
<td>Volcanic ash, baked black</td>
<td>1.0</td>
</tr>
<tr>
<td>Volcanic ash, whitish-grayish, yellowish with reddish streaks, cross-bedded; contains lumps of grayish-white pumice as much as 1 to 1 1/2 inches in diameter</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Since the time of Mansfield's visit, a large pumice pit has been developed at this place; it is now abandoned. Fifty to 75 feet of bedded, pumiceous material is exposed in the pit. The beds dip about 20°W. The pumice is similar to that mined near Ammon; the particles are white to light gray and range in size from fines to 2 inches across. Several beds of silt and ash, not more than 5 feet thick, can be seen interbedded in the pumice.
An abandoned pumice pit can be found at this locality southeast of Ammon in the NW1/4 of Sec. 23, T1N, R38E (Locality 6, Fig. 8). The pit is a wide trench several hundred feet long (Fig. 15); 75 to 100 feet of pumice is exposed on the sides of the pit. The upper 25 feet contains interbedded fine ash overlain by silt containing particles of pumice and volcanic glass. The series is capped by tuffaceous rhyolite about 10 feet thick.

Idaho Falls Pumice Co. - Sec. 23, T1N, R38E

Pumice mining operations are being conducted at this locality in Sec. 23, T1N, R38E by the Idaho Falls pumice Co., the only independent pumice producer that was operating in the Idaho Falls area at the time of this investigation. The pit is located at the edge of the foothills, as are the other pumice pits and exposures in the area, on the edge of the plain southeast of Ammon (Locality 7, Fig. 8). The pumice is mined by excavating a series of cuts parallel to the hillside. The overburden from succeeding cuts is used to fill the preceding cuts (Fig. 16).

The pumice is irregular in depth and lenticular. At this locality, where current mining operations are being conducted, pumice extends to depths of 75 to 80 feet. However, a short distance away the pumice is only a few feet thick as indicated by preliminary exploration (H. A. Harmon, Personal Communication, October 1963). The irregularity of thickness reflects the irregular surface upon which the pumice was deposited.

Thin clay seams that contaminate the product are encountered in the pumice deposit. When possible the clay is stripped from the cut as waste. Experience has shown that as mining proceeds farther into the hillside the clay seams become more numerous (H. A. Harmon, personal communication, October, 1963). Steep faults of small displacement, can be seen cutting the pumice. These are marked by small bands of clay or gouge that downgrade the pumice. Dips in the pumice deposit are gentle but highly variable.

The pumice is white to light gray: under the microscope it has a fibrous appearance, resembling many shards of fine volcanic glass packed tightly together. Many of the fibers are twisted and bent at various angles. The material is finely vesicular and hardly any alteration is evident. When powdered the pumice looks like typical volcanic glass.

A histogram showing the results of a screen analysis of a sample of pit-run material from the Idaho Falls Pumice Co. pit is shown in Figure 13. The unit weight of the material is 49 pounds per cubic foot.
A chemical analysis of the pumice from the Idaho Falls Pumice Co. pit is shown in Table 4.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Analysis</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>10.3</td>
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<td>SiO₂</td>
<td>63.8</td>
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<td>CaO</td>
<td>1.5</td>
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</tr>
<tr>
<td>MgO</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Na₂O</td>
<td>7.6</td>
<td></td>
</tr>
<tr>
<td>K₂O</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>5.4</td>
<td>98.5</td>
</tr>
</tbody>
</table>

Some of the pumice produced from this pit is used directly as pit-run material and some is screened and blended before use. Because Idaho Falls pumice has a long history of satisfactory use, its size distribution and chemical composition can be considered a useful guide to the quality requirements of a commercial pumice deposit.

NW1/4, Sec. 33, T2N, R39E

A measured section through a pumice exposure in the NW1/4 Sec. 33, T2N, R39E (Locality 8, Fig. 8) is presented by Mansfield (1952, p. 55); it is reproduced below:

1. Ash, rather coarse, well bedded, gray and drab, jointed normal to bedding, mingling at top with soil

2. Volcanic ash, well-bedded, grayish, coarse-textured; individual beds 1/8 in. to 3 in. thick, mostly containing rather large fragments of pumice; shows cross bedding and includes about 1 ft. of brownish dark material

3. Volcanic ash, coarse; pellets of pumice, 3/4 in. across; bits of rhyolite and obsidian; includes about 8 inches of fine ash, rather pinkish

4. Volcanic ash, coarse; pellets of pumice, and bits of rhyolite and obsidian as above
5. Volcanic ash, grayish-white, poorly exposed

6. Volcanic ash, gray and white, well bedded in coarser and finer beds 1/8 to 2 in. thick; coarser beds 4 to 8 in. thick contains pellets of pumice 1/2 to 3/4 in. in diameter with fragments of rhyolite

7. Volcanic ash, covered or not well exposed

8. Volcanic ash similar to Unit 6

9. Volcanic ash similar to Units 6 and 8

10. Covered

11. Volcanic ash, light-gray, in beds ranging in thickness from 1/8 to 1 in.; thinner beds of fine material and thicker beds of pumice fragments as much as 1/4 in. in diameter; occasional bits of obsidian; yellowish streaks; base not exposed

This section demonstrates the character of the upper part of a pumice deposit and the abundance of included volcanic ash.

Mansfield (1952, p. 54) notes the occurrence of basaltic tuff in the vicinity of Ammon. The largest accumulation is in Secs. 35 and 36, T4S, R39E and the adjoining parts of Secs. 1 and 2, T5S, R39E. Other exposures are in Secs. 1 and 12, T5S, R39E; Sec. 2, T5S, R39E; and Secs. 22, 26, and 27, T4S, R39E. The material is described as brownish or reddish scoria and ash, fragmental, friable and containing many gas cavities. The material is rudely bedded; it overlies the Salt Lake Formation. Easterly dips of 15° to 30° were noted at several places in the tuff; the beds strike north. The exposures, according to Mansfield, represent eroded tuff cones. These localities were not visited during this investigation.

The Idaho Falls Pumice Co. was the only independent pumice producer in the Idaho Falls area at the time of this investigation (October, 1963). Pumice Inc., another Idaho Falls based operation with a pit near Ammon, had recently ceased operations. The Idaho Concrete Pipe Co., of Idaho Falls, maintains pumice mining operations for internal company use.

The pumice mined by the Idaho Falls Pumice Co. sells for $1.65 per ton, pit-run material. Screened and sized pumice sells for $2.38 per ton (H. A. Harmon, personal
Fig. 9. Histogram showing size distribution of pumice, Sec. 8, T12S, R35E, Oneida County.

Fig. 10. Histogram showing size distribution of pumice, Sec. 23 and 26, T2N, R39E, Bonneville County.
Fig. 11. Histogram showing size distribution of pumice, Sec. 17, T2N, R39E, Bonneville County.

Fig. 12. Histogram showing size distribution of pumice, Sec. 14, T2N, R39E, Bonneville County.

Fig. 13. Histogram showing size distribution of pumice from Idaho Falls Pumice Co. pit, Sec. 23, T1N, R38E, Bonneville County.
Fig. 14. Photograph of pumice occurrence, Sec. 1, T2N, R40E, Bonneville County. Pumice in lower part of picture is overlain by silt.

Fig. 15. Photograph of typical pumice pit; Sec. 23, T1N, R38E, Bonneville County.

Fig. 16. Photograph of Idaho Falls Pumice Company pit, Sec. 23, T1N, R38E, Bonneville County.
communication, October, 1963). The product is used in Idaho and out-of-state; Montana is one of the principal consumers. According to Savage (1961b, p. 59), bulk pumice shipments have been made in 50 to 60-ton carload lots to such states as Montana, Utah, Wyoming, Nebraska, North Dakota, Minnesota and Kansas. Pumice production in other states and the rapid development of artificially expanded aggregates, such as expanded clays and shales, are reducing out-of-state market areas, however.

Some of the problems faced by the Idaho Falls pumice producers are increasing freight and production costs, decreasing market areas and depletion of easily accessible deposits near transportation facilities. Although pumice reserves are abundant, exploration for new deposits is hampered by extensive soil and rhyolite cover. Many of the soil-covered areas are valued for agricultural uses; consequently the acquisition and development of new deposits is expensive. Many pumice deposits of acceptable quality are not economic under existing conditions.

**Pumice - Teton County - T6N, R45E**

Just east of the town of Tetonia, in Teton County, a long north-trending ridge, capped by rhyolite, has pumice exposed on its south and west slopes. The pumice is intermittently exposed for a length of about a mile (Fig. 17). It is rudely bedded and about horizontal in attitude, although at one place a 6 degree northerly dip was noted. The deposits are friable and slightly cemented. Pumice particles, up to two inches across, occur in a matrix of fine, sand-size, pumiceous material. Pieces of obsidian are abundant in the pumice.

**SE Corner, Sec. 28, T6N, R45E**

In the SE corner of Sec. 28, T6N, R45E, on the south nose of the ridge, near the Tetonia cemetery, a small exposure of pumice can be seen at the head of a steep, south-trending gully (Locality 1, Fig. 17). The occurrence is undeveloped except for a small hand-dug trench on the east side of the gully. The trench exposes pumice through a vertical distance of about 10 feet for a distance of 20 feet. There are no other pumice exposures in the vicinity but further exploratory work would probably indicate more pumice on both the east and west sides of the draw. Spherulitic rhyolite outcrops near the top of the ridge; large rhyolite boulders mantle the slope from the pit to the ridge line.

The deposit is a friable mass of pumice fragments, up to an inch across, enclosed in a groundmass of finer fragments. Many of the larger particles will float on water. The pumice is white to light gray in color and finely vesicular. A screen analysis of the material from Locality 1 gives the size distribution shown in Fig. 19. A histogram of the size distribution of the pit-run material from the Idaho Falls Pumice Co. pit in Bonneville County is also shown in Figure 19 for purposes of comparison. The histograms show that the particle size of the material
in the two deposits is similar. Analyses represent pit-run material with no crushing, screening or blending. Tetonia pumice has a unit weight of 51.5 pounds per cubic foot.

A chemical analysis was made of the pumice to help evaluate its suitability as aggregate. The results of the analysis are shown in Table 5. The material is similar in composition to Idaho Falls pumice but it has a slightly higher Al₂O₃ content.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Analysis</th>
<th>Sec. 28, T6N R45E, Teton County</th>
<th>A. M. Lothe, Analyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td></td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Al₂O₃</td>
<td></td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>SiO₂</td>
<td></td>
<td>62.7</td>
<td></td>
</tr>
<tr>
<td>CaO</td>
<td></td>
<td>1.7</td>
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</tr>
<tr>
<td>MgO</td>
<td></td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Na₂O</td>
<td></td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>K₂O</td>
<td></td>
<td>9.0</td>
<td></td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>5.6</td>
<td>99.5</td>
<td></td>
</tr>
</tbody>
</table>

Center Sec. 28 - T6N, R45E

In the approximate center of Sec. 28, T6N, R45E a pit exposes pumice near the top of the ridge about 800 feet east of the Tetonia water tower; the tower is about 0.3 mile east of the main highway in Tetonia (Locality 2, Fig. 17). Over an area approximately 200 feet by 200 feet pumice is exposed through a vertical distance of 30 feet; the full thickness was not determined. A layer of fine, sandy ash, about 5 feet thick is interbedded in the pumice 10 feet below the top of the exposure. The beds strike N60E and dip 6 degrees north.

Soil and vegetation occur south of the pit, and rhyolite caps the ridge to the north. There is a south-trending draw east of the pit; trenches on both slopes of this draw do not pass through the overburden and expose the underlying material.

This pumice resembles that from Locality 1 farther south except that the particles are not as strong and the fragments are finer. By comparing the screen analysis of the material from Locality 2 (Fig. 17) given in Fig. 20, to the screen analysis of the sample from Locality 1 (Fig. 17), it is noted that only 32 percent of the material is larger than 14 mesh (0.046 inch) versus 52 percent at Locality 1. The sample from Locality 2 excluded the interbedded sandy ash. The particles will float in water for only a brief time and sink as the pore spaces are filled. Under the microscope the particles resemble
Figure 17—Location Map Of Pumice Deposits, T 6 N, R 45 E, Teton County.
Figure 18 — Sketch Map Of Pumice Occurrence, Sec. 21, T 6 N, R 45 E; Teton County.
Fig. 19. Histogram showing size distribution of pumice, Sec. 28, T6N, R4SE, Teton County; with a comparison to Idaho Falls pumice, Sec. 23, T1N, R3SE, Bonneville County.

Fig. 20. Histogram showing size distribution of pumice, Sec. 28, T6N, R4SE, Teton County

Fig. 21. Histogram showing size distribution of pumice, Sec. 21, T6N, R4SE, Teton County.
aggregates of volcanic glass. Many of the particles have a silvery white sheen on their surfaces.

Local residents report that the material extracted from the pit has been used for lightweight aggregate in building block manufacture at a plant near Rexburg. No information could be obtained on the performance and quality of products made with this material.

Center Sec. 21, T6N, R4SE

Near the center of Sec. 21, T6N, R4SE, about a mile west of the railroad pumice is again exposed (Locality 3, Fig. 17). On the nose of a ridge between two west-trending draws, a small trench has been excavated in pumice. The exposure is 20 to 30 feet long and the pumice is exposed through a vertical distance of 15 feet. At the base of the exposure the lower two feet is much finer than the overlying material. Figure 18 is a sketch showing the relative location of the pumice exposures at this locality.

On the north slope of the more southerly draw at about the same elevation as the exposure just described and about 300 feet east of it, pumice is again exposed by a small pit. About 200 feet farther east on the same slope of this draw, there is a 30-foot exposure of pumice, 50 to 75 feet higher in elevation than the exposure to the west. The pumice is exposed in a bulldozer cut; the top of the cut is about 75 feet below the top of the ridge; rhyolite float mantles the intervening slope. Directly across the draw, on the south slope, there is a small exposure of pumice, poorly revealed in a small cut. Soil and rhyolite boulders occur above the cut. About 250 feet west of this most easterly exposure, on the south slope of the draw, a pit has been dug, but no pumice is exposed. Rhyolite occurs in the banks of the pit, but it was not determined if the rhyolite is in place or is float.

The pumice at this locality appears to be 50 to 75 feet thick and, as exposed in the draw, occupies an area about 500 feet by 200 feet.

A screen analysis of pumice samples taken at this locality gave the results shown in Figure 21. This material is similar in size distribution to that from Locality 1 (Fig. 17) and also to material produced by the Idaho Falls Pumice Co.

On the basis of this preliminary examination, pumice resources in the vicinity of Tetonia are extensive. It appears that there may be some variation in the particle size of the material at different localities and that not all the pumice would be suitable for aggregate. In general, the Tetonia pumice is similar to that at Idaho Falls and the deposits are similar in character. Thus it can be expected that there is considerable variation in the thickness of the deposits and in the size distribution of the included material.
Pumice - Blaine County - Sec. 6, T1S, R21E

Just south of State Highway 23, between Carey and Picabo in Blaine County, a deposit of volcanic ash, pumice and perlitic sand occurs in Secs. 31 and 32, T1S, R21E. Beds of pumice, ash, perlitic sand, tuffaceous sandstone and impure diatomite occur along the north and west flanks of a rhyolite capped ridge north of the junction of Silver Creek and Little Wood River. The deposit is on the west side of the divide between these two streams (Fig. 41).

About 40 feet of pumice and perlitic sand are exposed in a pit about 400 feet above the floor of Silver Creek valley; the pit is about a quarter of a mile south of the highway on the west slope of the ridge. No other pumice exposures were seen in the vicinity, but if exploration pits were dug at about the same elevation around the flank of the ridge, chances are that more pumice would be found. The exposure is underlain by volcanic ash which appears to extend to the valley floor, but exposures are very poor. If this ash is similar to that exposed on the north side of the ridge, it is interbedded with tuffaceous sandstone and impure diatomite. The volcanic ash is discussed more fully in the section of this report dealing with pumice.

The pumice is composed of strong, hard particles 1/4 to 3 inches across in a matrix of fine pumiceous material and perlitic sand. The particles are angular and somewhat brittle, the pumice is light gray in color and finely vesicular.

The perlitic material associated with the pumice is a sand composed of particles of perlitic glass, glass shards and rounded obsidian fragments. The perlitic material expands readily on heating. Some of the perlitic glass occurs in bands or streaks in the pumice giving a banded appearance to the particles.

The base of the rhyolite capping the ridge is not well exposed, however indications are that conditions favorable to the formation of perlite existed when the flow was extruded, as shown by the presence of perlitic particles in the pumice. On the north side of the ridge it appears that the volcanic ash and associated material accumulated in a ponded environment. If such a locality was rapidly covered by an extruded flow, the quick cooling and abundance of moisture, would be favorable to the formation of perlite at the base of the flow.

At this locality there is a good possibility that deposits of pumice and perlite could be discovered and developed by detailed prospecting. The prospecting would have to include trenching or some means of removing overburden, however.

Challis Volcanics are shown in this area by Ross and Forrester (1947). The ash, pumice and sedimentary material probably represents a local exposure of the Germer Tuffaceous Member of the Challis Volcanics.
About 6 miles west of the junction of State Highway 68 and U. S. 93, in Blaine County, pumice is exposed by pits and trenches over a broad area in the south half of Sec. 14, T18S, R17E. The pumice occurs north and south of Highway 68 at the north end of Magic Reservoir (Fig. 22).

The pumice is associated with a series of acidic lava flows called the Magic Reservoir Rhyolite by Malde and others (1963). The Magic Reservoir Rhyolite is made up chiefly of rhyolite tuff, densely welded and rich in large phenocrysts of quartz and sanidine held in a pale, purplish-gray aphanitic groundmass. Vent areas are characterized by vertical and outward dipping flow banding and by massive outcrops. The series is at least 500 feet thick southwest of Magic Reservoir (Malde and others, 1963).

There is lack of sorting in the pumice deposit, an absence of finer pumicite, and abundant intermingled angular fragments of rhyolite and obsidian. These features indicate that the pumice occurs in a vent area; it is probably on the slope of an eroded cone. Granitic intrusive rocks occur east of the deposit and Quaternary basalts cover the area to the southwest. According to Malde and others (1963), three other vent areas of Magic Reservoir Rhyolite occur southeast of Magic Reservoir along Highway 93; no associated pumice was found at these localities, however.

Magic Reservoir is at the south base of the ridge upon which the pumice occurs. The pumice exposures are on the north side of this ridge (Fig. 22). No pumice outcrops were seen on the south slope but pumiceous float is abundant. Trenching would probably be required to expose pumice on the south slope. The ridge is capped by rhyolite tuff.

Rhyolite and rhyolite tuff outcrop north of the pumice deposit. Pumice might also be exposed in this vicinity if the capping material was removed (Fig. 22).

The particles in the deposit are highly variable in size; they range from 1/2 inch to 8 inches across. About half of the material is larger than 1 1/2 inches in diameter. The pumice is tan in color, the fragments are hard, abrasive and angular. No bedding is noticeable in the pumice deposit and there seems to be a complete lack of sorting. Large angular fragments of rhyolite and obsidian are abundant in the deposit (Fig. 23). In the northwest part of the deposit it appears that a rhyolite tuff flow is interbedded in the pumice.

A screen analysis of a sample from this deposit gave the size distribution shown in Figure 24. The unit weight of the material was determined to be 27 pounds per cubic foot. When crushed to the proper size for aggregate, the unit weight would be increased, however.
A chemical analysis of the pumice from this deposit gave the results presented in Table 6. The pumice is similar in composition to the other pumice deposits investigated in the state. It shows more Al₂O₃ than Idaho Falls pumice, but it is very similar chemically to the commercial pumice deposit in Oneida County.

<table>
<thead>
<tr>
<th>TABLE 6 - Chemical analysis of pumice, Sec. 14, TIS, R17E, Blaine County (A. M. Lothe, Analyst)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
</tr>
<tr>
<td>Al₂O₃</td>
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<td>K₂O</td>
</tr>
<tr>
<td>Loss on ignition</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Staley (1950, p. 6-7) says that the Sun-ite Corp., 801 Continental Bank Bldg., Salt Lake City 13, Utah, is interested in this deposit. This is the earliest reference to the commercial development of this pumice that could be found. The Minerals Yearbook of the U. S. Bureau of Mines for 1954 (v. 1, p. 952) says that

"... an open-pit pumice operation reportedly began near Bellevue, Blaine County, Idaho. The Sun-ite Sales and Manufacturing Company, Elko, Nevada, planned to use the material as lightweight aggregate with gypsum in flagstone, roofing tile, and prefabricated houses."

It is not known which address is correct for this company. The Minerals Yearbooks for 1955 and 1956 report that the mine was idle during these years. In 1957 the U. S. Bureau of Mines Minerals Yearbook (v. III, p. 368) reported that a small tonnage was produced. No further indications of activity could be found concerning this deposit.

Staley (1961) mentions reported difficulties experienced in getting a good mix with Magic Reservoir pumice; the pumice does not bond well with cement for some undetermined reason. Otherwise, the pumice is said to be the best as far as physical properties are concerned.

Although the deposit is only some 50 miles north of the Twin Falls and Jerome market areas for pumice, consumers in these localities prefer Idaho Falls pumice; Idaho Falls is more than 200 miles distant from these markets. The Idaho Falls material is better graded, less abrasive, and white in color. Because of lack of markets and problems of bonding in cement, the deposit has not been extensively
Figure 22 - Map Showing Area Of Pumice Outcrop, Sec.14, T1S, R14E, Blaine County.
Fig. 23. Photograph of pumic pit, Sec. 14, T1S, R17E, Blaine County. Note large rhyolite fragments in pumice near top of bank.

Fig. 24. Histogram showing size distribution of pumice, Sec. 14, T1S, R17E, Blaine County.
According to Staley (1950, p. 6), the Magic Reservoir pumice is found in Secs. 15, 22 and 23, T18S, R17E, as well as in Sec. 14. These sections were checked for pumice but none was found. Basalt outcrops over most of Secs. 22 and 23; most of Sec. 15 is covered by heavy soil and vegetation.

**Pumice - Camas County - Sec. 30, T1N, R16E**

A small exposure of pumice can be seen at the head of a small draw that is tributary to Willow Creek on the east in the SE1/4 of Sec. 30, T1N, R16E. The pumice is located on the property of Angus Brooks. The exposure is reached from the Willow Creek road. About three-quarters of a mile north of the Willow Creek school-house, at the Angus Brooks farm, a dirt road leads west up the draw. The pumice is about 1 1/2 miles west, of the farmhouse. The locality is about 10 miles east of Fairfield in Camas County.

A pit exposes 10 feet of altered pumice with an abundance of admixed soil. Many of the particles are soft and clay-like; they show pumiceous texture, but they are highly altered. These particles break down in water to soft masses of clay. Other particles appear fresh; they will float on the surface of the water but they become saturated quickly and sink. All of the particles lack strength and are easily crushed. Most of the pumice particles are 4 mesh (0.185 inch) or smaller in size. Angular pieces of rhyolite up to one foot across can be seen in the deposit.

Rhyolite and rhyolite tuff cap the surrounding ridges. The pumice at the head of the draw is the only such exposure in the area. The exposed portion possibly represents a surficial altered zone; the quality of the material might improve with depth. In addition, further exploration laterally by pits and trenches to remove cover might show better quality pumice.

**Pumice - Reported areas of occurrence**

**Rhyolitic cones, Caribou County, T7S, R41, and 42E**

Three rhyolitic cones stand at the south end of Blackfoot Reservoir. The largest of these, located about 10 miles north of Soda Springs in the NE1/4 Sec. 13, T7S, R41E, is called China Hat. Middle cone is about a mile northeast of China Hat in Sec. 18, T7S, R42E, and North cone is about 2 1/2 miles northeast of China Hat in Sec. 5, T7S, R42E (Fig. 71). The alignment of these cones in a northeasterly direction is a noteworthy feature and suggests that their location is controlled by some large structural feature, such as a fissure or rift zone.

These cones were investigated as a possible source of pumice, but no suitable material was found. The cones are composed of hard, indurated pumiceous
ryolite and vitric tuff. Mansfield (1927, p. 117) remarks that the cones are built of pumiceous, glassy and perlitic rhyolite, locally like obsidian, not generally distinguished as separate flows. The cones are surrounded by younger basalt.

Although no pumice, ash or other friable pyroclastic material related to these cones were found, Mansfield (1927, p. 118) describes a cut in the bank of the Blackfoot River east of China Hat, that he saw in 1912. The cut exposed the following section:

Section of west bank of Blackfoot River in NE1/4  
Sec. 16, T7S, R42E (Mansfield, 1927, p. 118)

<table>
<thead>
<tr>
<th></th>
<th>Ft.</th>
<th>In.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Soil at top of section</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>2. Volcanic ash, white, horizontal beds, fine-textured</td>
<td>13</td>
<td>-</td>
</tr>
<tr>
<td>3. Volcanic ash, dark, with fragments of basalt as much as 3 inches in diameter</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>4. Volcanic ash, white, like bed No. 2, to water level</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>47</td>
<td>-</td>
</tr>
</tbody>
</table>

A search for this or similar exposures was made but none was found. The ash described was probably erupted from one or more of these three cones.

Reportedly, (Mansfield, 1927, p. 117) the islands in the Blackfoot Reservoir in Secs. 11 and 14, T6S, R41E are made up of rhyolitic material also.

**Big Southern Butte, Butte County, SE Corner T1N, R29E**

Big Southern Butte rises above the surrounding lavas of the Snake River Plain in Butte County about 20 miles southwest of Arco. The butte is a prominent landmark in the region; its summit is some 2,500 feet above the plain in the southeast corner of T1N, R29E.

According to Storms and others (1938, p. 35) the butte is composed of basaltic and rhyolitic flows of different textures. The main mass is porphyritic rhyolite; the bulk of the material is glassy or pumiceous. The summit is made up largely of huge blocks of white pumice and a few obsidian bands. In places beneath the coarse ejecta-menta, beds of white ash and agglomerate crop out.
The north slope of the ridge and the western summit were investigated during this examination. Most of the outcrops are rhyolite and vitric tuff; they are of little interest as volcanic construction materials.
PUMICITE

INTRODUCTION

Pumicite or volcanic ash (the two terms are synonymous and can be used interchangeably) is a widespread commodity in Idaho. The market for this material is extremely limited, however, and so far as is known, no significant production of volcanic ash has taken place in the state.

The greatest possible use of western pumicite is as pozzolanic material and this use is regarded as having the greatest potential for commercial development. Prior to World War II abrasives used in cleansing preparations, rubbing compounds and the like, constituted a large market for fine, pure pumicite. However, artificial materials, and pumicite imported on the Eastern Seaboard, have displaced western pumicite from this market.

Several states, notably Kansas, (Bauleke, 1962) and Oklahoma (Burwell, 1949), have issued publications dealing with the products of expanded ash and its possible commercial applications. Most of this work has been done on an experimental basis only, but it shows promise of developing an inexpensive source of lightweight aggregate, insulating material and filter media.

POZZOLANS

Definition

Pozzolans are defined by the U. S. Bureau of Reclamation (1955, p. 81) as:

A siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

Development of pozzolan industry

Cements and pozzolan cements have been in use for some 2000 years. The early Greeks and Romans produced mortar by calcining limestone and the product was used with water or with water and aggregate as a cementing material. These early builders discovered that mortars containing volcanic ash as aggregate were stronger and more durable than others and in addition they were hydraulic. Large quantities of volcanic ash were found near the village of Pozzouli, hence the name pozzolan. Later the Romans discovered that other substances, such as ground brick, tile, or pottery would also serve as pozzolan (Mielenz, 1950, p. 1).
During the Middle Ages the art of cement manufacture was lost. Consequently the use of concrete construction was of little significance until the invention of portland cement at the beginning of the nineteenth century (Mielenz, 1950, p. 2). The development of portland cement greatly increased concrete construction but the use of other types of hydraulic cement was reduced because of the superior concrete produced with portland cement.

It has been known for many years that the replacement of a portion of the portland cement (10 to 30 percent) by pozzolan in a concrete mix brings about certain improvements and advantages; control of alkali-aggregate reaction is an especially desirable advantage. In the U.S. pozzolanic admixtures have only been used extensively in the construction of large, massive, concrete structures. Pozzolans were used during construction of the Los Angeles Aqueduct, the San Francisco Bay Bridge, the Golden Gate Bridge and Friant Dam, California; Bonneville Dam, Washington-Oregon; Altus Dam, Oklahoma; Davis Dam, Nevada-Arizona; and Hungry Horse and Canyon Ferry Dams, Montana (Mielenz and others, 1951, p. 313). There are 3,086,000 cubic yards of concrete in Hungry Horse Dam containing 126,000 tons of Chicago fly ash, the material used as pozzolan. Reportedly a saving of $1,500,000 in materials cost resulted from the partial replacement of cement by fly ash during construction of the dam (Snyder, 1964, p. 16). Portland-pozzolan cement has been used in most of the concrete dams built by the Federal Government in recent years.

The successful use of pozzolan in large structures has created interest in their application to general concrete construction and considerable research has been done in this respect. As of yet portland-pozzolan cement has not been widely accepted, but its use will undoubtedly increase significantly in the future.

Advantages and disadvantages of pozzolan

Portland-pozzolan cement ordinarily costs less; in concrete the heat of hydration is lower and the maximum rate of heat development is reached at an earlier age; grindability of the concrete is improved; plasticity of the fresh concrete is increased; and separation of the constituents of the concrete and bleeding of water are generally decreased. In addition, permeability of the concrete characteristically is decreased; resistance to attack by sulfate-bearing water is increased; tensile strength is typically improved. Certain pozzolanic admixtures eliminate or greatly retard reactions between cement alkalies and aggregates (Mielenz and others, 1951, p. 313).

Several deficiencies in the quality of concrete may be introduced if inferior pozzolans are used or if excessive replacement is attempted. A replacement of 10 to 30 percent is generally the accepted range. The rate of hardening and development of compressive strength and elasticity of the concrete can be retarded; shrinkage due to drying may be increased and resistance to freezing and thawing might be reduced. Some pozzolans otherwise suitable, have been found to increase deterioration resulting from alkali-aggregate reaction (Mielenz and others, 1951, p. 313).
The U. S. Bureau of Reclamation (1955, p. 48) says that pozzolans are not specified for a job unless a definite advantage is to be gained from their use. The Bureau of Reclamation also notes that some pozzolans increase the water requirement of the mix; consequently additional cement is required to meet a specified water-cement ratio and to assure that the concrete will meet design strengths. The additional cement increases the cost of the concrete and the additional water increases drying shrinkage. Investigations by the Bureau of Reclamation have shown that concrete containing pozzolan must be carefully cured; otherwise its resistance to freezing and thawing may be reduced.

Best results are attained if the pozzolan to be used on a specific job is thoroughly tested in combination with the cement and aggregate to be used; thus the advantages and disadvantages of the pozzolan, with respect to quality and economy of the concrete, can be determined.

**Materials of pozzolans**

According to Mielenz and others (1951, p. 311) pozzolans are of two kinds: natural and artificial. Natural pozzolans can be divided into two types—those in which the materials are originally pozzolanic and those in which pozzolanic activity can be induced by heat treatment. The natural pozzolans owe their activity to the presence of one or more of the following substances: (1) volcanic glass, (2) opal, (3) clay minerals, (4) zeolites, and (5) hydrated oxides of aluminum. Artificial pozzolans such as fly ash, ground brick, burned oil shale and others, owe their pozzolanic activity to glasses formed by fusion or chemical reconstitution of the components of the original material.

Table 7 is a classification, suggested by Mielenz and others (1951, p. 317) of natural pozzolans based upon the material present as the active ingredient, whether heat treatment (calcining at temperatures less than 2000° F), is required or not.

**TABLE 7 - Classification of natural pozzolans, based on active ingredients (from Mielenz and others, 1951)**

<table>
<thead>
<tr>
<th>Activity type</th>
<th>Active ingredient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Volcanic glass</td>
</tr>
<tr>
<td>2</td>
<td>Opal</td>
</tr>
<tr>
<td>3a</td>
<td>Kaolinite-type clays</td>
</tr>
<tr>
<td>3b</td>
<td>Montmorillonite-type clays</td>
</tr>
<tr>
<td>3c</td>
<td>Illite-type (hydromica) clays</td>
</tr>
<tr>
<td>3d</td>
<td>Mixed clays with altered vermiculite</td>
</tr>
<tr>
<td>4</td>
<td>Zeolites</td>
</tr>
<tr>
<td>5</td>
<td>Hydrous aluminum oxides</td>
</tr>
<tr>
<td>6</td>
<td>Nonpozzolans</td>
</tr>
</tbody>
</table>
In some instances a material may consist of more than one chemically active ingredient; it is then classified as a mixed activity type.

Because the purpose of this report is to evaluate the occurrences of volcanic construction materials in Idaho, volcanic ash deposits containing volcanic glass as the active ingredient are discussed at some length in this report. Other activity types, including the mixed types, are only incidentally included. Occurrences of mixed diatomite and volcanic ash or diatomite, volcanic ash and clay of one kind or another, are fairly abundant in the Tertiary sediments of southern Idaho, particularly in the Idaho Formation, but such deposits were investigated only when the dominant constituent of the material was volcanic ash. Several minor occurrences of bentonite (montmorillonite-type clay) were also investigated in connection with this report; these can also be considered potential sources of pozzolan.

**Specifications covering pozzolans**

Table 8 is a tabulation of the specifications for natural pozzolanic materials established by the U. S. Bureau of Reclamation in 1961.

**TABLE 8 - Chemical and physical specifications of pozzolan required by the U. S. Bureau of Reclamation (from U. S. Bureau of Reclamation 1961)**

**Chemical composition**

- Silicon dioxide (SiO₂), plus aluminum oxide (Al₂O₃), plus ferric oxide (Fe₂O₃), not less than 75.0%
- Magnesium oxide (MgO), not more than 5.0%
- Sulfur trioxide (SO₃), not more than 4.9%
- Loss on ignition, not more than 10.0%
- Moisture content, not more than 3.0%
- Exchangeable alkalis as Na₂O, not more than 2.0%

**Physical properties**

- **Fineness:**
  - Specific surface, square centimeters per cubic centimeter (solid volume), air permeability fineness method of test; not less than 16,500
  - Material retained on No. 325-mesh sieve, per cent, not more than 12

- **Compressive strength:**
  - With portland cement, percent of control, 28 days, not less than 80
  - With lime, 7 days, minimum pounds per square inch 800
  - Change of drying shrinkage of mortar bar: percent shrinkage of pozzolan bar minus percent shrinkage of control bar, not more than 0.04
  - Water requirement, not more than 112%

**Reactivity**

- Reduction of expansive reaction at 14 days, not less than 60%
TABLE 8 (Continued)

Others

Any pozzolan having abnormalities with respect to hardening, setting, rate of heat of hydration, or any other abnormality not specifically covered in these specifications, as determined by preliminary test, will not be approved.

The specifications given in Table 8, cover natural pozzolans which may or may not require calcination, at temperatures not less than 1400°F, nor more than 1800°F, or grinding to meet the requirements.

The U. S. Army Corps of Engineers (1961) has established specifications for pozzolan that, with slight differences, correspond to those established by the Bureau of Reclamation. The Corps of Engineers specify only 70 percent \( \text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 \) as opposed to 75 percent by the Bureau of Reclamation; the Corps of Engineers permit available alkalis of only 1.5 percent as compared to 2.0 percent by the Bureau of Reclamation. There are similar small differences in the specifications for the physical requirements of the material.

It is obvious that careful testing of pozzolans must be done before they are used. Because much of the testing must be done in conjunction with the cement and aggregate to be used on the specific job for which the pozzolan is intended, no attempt was made to carry out complete tests on the samples from deposits investigated. All samples collected were examined microscopically. Sieve analyses and chemical analyses were carried out on selected samples chosen in regard to the location of the deposit, its size, and the results of the microscopic examination done beforehand. The results of this work are presented in the section of this report dealing with individual pumice deposits. Sieve analyses are presented as histograms; the detailed sieve analyses are shown in the appendix.

VOLCANIC GLASS AS POZZOLAN

Features of suitable pumice pozzolan

Pozzolans of Activity Type 1 (volcanic glass) include rhyolite tuffs and pumicites and some dacite tuffs and pumicites. Andesitic tuffs and pumicites may possibly be suitable. Basalt tuffs and ashes (cinders) are unsatisfactory (Miezenz and others, 1951, p. 319). Generally the pumicites are more satisfactory than the tuffs from an economic point of view because of the fineness requirement of pozzolans; grinding can become a major production cost.
Mielenz and others (1951, p. 319) says that pozzolans of Activity Type 1, that owe their pozzolanic activity to volcanic glass alone, must contain at least 60 percent glass in order to achieve a satisfactory mortar strength. In addition, 90 percent or more of glass must be present in order to effectively control alkali aggregate reaction, unless other active constituents are present. Petrographic and chemical analyses alone will not indicate the suitability of a pumicite as a pozzolan. Fineness of the material must be considered and in some instances, exceptional stability of the glass may cause unsatisfactory results. In some volcanic pozzolans alkalies may be present and the alkali aggregate reaction may be increased. It should be stressed that the only positive means of evaluating a pozzolan such as pumicite is by testing with cement and mortar.

Mielenz and others (1951, p. 321) states that the compressive strength of mortars containing pozzolan of Activity Type 1 ranges from 64 to 131 percent of the control sample containing no pozzolan. However, a value as high as 172 percent has been reported (Klemgard, 1958, p. 22). A relative compressive strength of 80 percent is usually considered adequate (Mielenz and others, 1951, p. 321).

A reduction of 25 percent of the expansion caused by alkali aggregate reaction of a control specimen containing no pozzolan is usually considered satisfactory for a pozzolanic material. Mielenz and others (1951, p. 321) have found values ranging from 14 percent to 78 percent for volcanic glasses.

In general, pumicites are excellent pozzolans, but the results obtained with materials from different deposits vary widely, even though the physical and chemical characteristics of the materials may be very similar.

**OTHER USES OF PUMICITE**

**Abrasives**

Pumicite and ground pumice were used extensively for abrasives prior to World War II. Processed materials found wide use in soaps, tooth pastes, powders, rubber erasers, tracing cloth preparations and other applications. Powders were once popular for rubbing down wood and metal surfaces and paint and varnish finishes; manufacturers of furniture and automobiles were large consumers of pumice and pumicite powders as were makers of cutlery, surgical instruments and other tools requiring a fine polish (Williamson and Burgin, 1960). Finely ground silica and artificial products have largely displaced pumicite and pumice from the abrasive market; some makes of specialized cleaning preparations and abrasives contain pumice or pumicite but materials imported on the Eastern Seaboard supply much of the demand. Much of the pumicite formerly used as abrasive was mined in the midwestern states; Idaho pumice and pumicite have never helped supply this market.
Ceramic compositions

Bauleke (1963, p. 17) lists the ceramic applications of volcanic ash as follows:

1. a flux to reduce the vitrification temperature of ceramic compositions used in whiteware and structural clay products

2. a material for low-cost glazes used on structural clay products, wall tile, sanitary ware, and ceramic artware.

3. a source of potassium oxide in the manufacture of iron-containing glasses

4. when mixed with limestone, volcanic ash could form the basis for a cheap glass into which radioactive waste could be incorporated as an insoluble solid before being dumped into the earth for storage

Bauleke (1963, p. 16) notes that volcanic ash used in ceramic applications must be essentially iron free if a pure white body is desired; iron oxide will cause staining and discoloration, if present.

Plans to evaluate the ceramic possibilities of volcanic ash found in Idaho have been discussed with members of the Metallurgy Department of the College of Mines at the University of Idaho. Experimental work on this and other applications of volcanic ash will soon be initiated.

Bloated ash

Experimental work by the Kansas Geological Survey has shown that ash can be successfully "popped" or bloated (Bauleke, 1963). The ash is injected into the air intake of a gas burner, so that the ash is mixed with the air consumed during combustion of the gas. According to Bauleke (1963, p. 10) the particles of glass are softened during heating and absorbed gases expand them into spheres; as soon as the particles leave the flame they are solidified by sudden cooling. The expanded particles are exhausted into a collection chamber.

Some difficulty was encountered in measuring the bloating temperature required, but it appeared to be between 1600° and 1700° F.

It was found desirable to feed the particles into the flame rapidly to obtain a material with a low bulk density. The raw ash used in the experiments averaged 66 pounds per cubic foot and run-of-the-mill bloated ash had a bulk density between 12 and 25 pounds per cubic foot, a reduction of 62 to 82 percent. It was also found that as the sizes of the bloated particles decreased the bulk density increased; by careful screening, a product with a bulk density of 2 1/2 pounds per cubic foot could be obtained.
Some of the uses of bloated ash pointed out by Bauleke (1963, p. 12-14) are as a filtration medium, a substitute in plaster mixes, as thermal insulation and fire-proof acoustical tile.

As a filtration medium the particles may be used crushed or uncrushed. The filtration rate through uncrushed particles was found to be greater because of larger pore spaces; excellent results were obtained by gently crushing the spheres to produce cracking but not shattering of the particles.

Two methods of developing a filter medium are suggested by Bauleke (1963, p. 12):

1. selective screening of the bloated ash separates a low bulk density product (about 4 pounds per cubic foot). Gentle crushing of the low-bulk-density fraction then raises its density to 7 or 8 pounds per cubic foot, but it has the advantage of mixing large and small particles, forming a tight filter mat.

2. fine crushing of the bloated ash (less than 10 microns) and air classifying the material into a narrow range of particle sizes. The resultant small ash particles of uniform size pack with a maximum of tiny pore spaces, forming a good filter mat.

Filter media are used in food and petroleum processing and water treatment; these are uses that could consume large tonnages of bloated ash if the filtration processes were developed commercially.

Although bloated ash particles have thin cell walls and are fragile, it is possible that stronger particles, of the proper size, could be produced and used as a direct substitute for perlite in plaster mixes by agglomeration. Some of the denser bloated ash could be used as a substitute for sand in plaster mixes as well, especially in the manufacture of plaster wallboard (Bauleke, 1963, p. 13).

Bloated ash has excellent insulating properties and could prove useful as loose-fill insulation in wall spaces, in cavities in building blocks, and other openings (Bauleke, 1963, p. 14).

When the bloated ash was mixed with a noncombustible silicate binder, pressed, and oven-cured at 200° F, an acoustical fire-proof tile was produced. The transverse breaking strength of the tile was 150 pounds per square inch; a strength suitable for non-load bearing applications such as ceiling tile. The strength can be improved by addition of organic fiber without reducing the fire resistant qualities. Dusting or rubbing off of ash particles from the tile surface can be prevented by the use of a fire-resistant paint (Bauleke, 1963, p. 14).
Burwell (1947, p. 24) has discussed the results of experimentally bloating volcanic ash in bulk rather than "popping" individual particles. The ash was placed in a crucible, or mold, for large-scale tests, and the material was heated in a furnace to the softening temperature. Initial bloating took place between 1175°C and 1225°C (2147°F to 2237°F), a range of only 50°C. Impure volcanic ash containing bentonite, and volcanic tuff, had a shorter bloating range, that is, the progress of bloating was more rapid, but the initial softening temperature was the same.

The effect of time of exposure to the bloating temperature was also studied by Burwell (1949, p. 23). At 1200°C the effect of time of exposure had little influence on the degree of expansion but at temperatures of 1250°C and 1300°C, it was noted that an exposure of 15 minutes at 1300°C was equivalent to one hour at 1250°C. A lower viscosity allows an increase in cell size up to the point where the cell walls collapse because of internal pressure; prolonged heating, at temperatures which lower the viscosity of the mass, has a tendency to cause coalescence of the cell walls with the creation of larger cells having heavier walls.

According to Burwell (1949, p. 26) there is a correlation between chemical composition and bloating characteristics. In general, the ratio of silica to alumina and to alkali and alkaline earth fluxing agents is of primary importance. The samples with relatively low alkaline earth and high alkaline content yielded a satisfactory product; those with the reverse ratio did not.

The cause of bloating or the gas responsible for it was not determined. Burwell (1949, p. 27) suggests that oxygen liberated during the disassociation of ferric oxide is the activating agent. The conditions necessary to produce bloated ash are summarized by Burwell as follows:

(1) that gas, gases or vapor will be generated from and within itself when heated to temperatures that cause the mass to be thermoplastic, and (2) that the mass will be sufficiently viscous, while in the thermoplastic stage, that it will hold the gas, gases or vapor, in non-connecting voids, and on cooling the mass will retain the form and cellular structure caused by the expanded gas during the thermoplastic stage.

The addition of caustic soda to the ash lowered the bloating temperature and yielded a product that contained a large percentage of open pores, weighed less than 35 pounds per cubic foot and resisted crushing up to about 1080 pounds per square inch (Burwell, 1947, p. 34).

The product derived from bloated ash in bulk form resembles foamglass, an expanded product made from manufactured glass. The pressure required to crush the bloated ash ranged from 250 pounds per square inch to 5000 pounds per square inch.
The least bloated material had the greater strength. The material was more resistant to horizontal pressure than vertical pressure. The average cell size ranged from 0.02 to 0.30 millimeters and cell sizes in individual samples were fairly constant. Bulk specific gravity ranged from 45 to 90 pounds per cubic foot (Burwell, 1947, p. 30-31).

Bloated ash could find use as an insulation material. Bloated products made from ash and caustic soda should possess good acoustical properties because of the high porosity of the material. Its use as tile and sound-proof partitions is suggested (Burwell, 1947, p. 39-40).

As indicated by both Bauleke (1963) and Burwell (1947), there is variation in the expanding and bloating characteristics of ash from different deposits; according to Burwell, the variation is due, at least in part, to variation in chemical composition. Plans to check material from Idaho pumicite deposits for expanding characteristics and possible commercial applications have been made; this work will soon be under way.

Miscellaneous uses of volcanic ash

Volcanic ash has been applied as top dressing to blacktop highway surfaces to improve light reflectivity (Bauleke, 1963, p. 15). Volcanic ash is useful as an absorbent for oil and grease and has been used by garage owners for this purpose. Ash is also used as inert fillers, extenders and carriers in manufactured products such as insecticides. It has been used as an anti-skid material and as a plant fertilizer. Most of these uses are of limited importance economically and in general are employed only when the source of the ash is nearby and it is readily available.

A possible application of volcanic ash might be as road surfacing material for unpaved roads, where sources of gravel or volcanic cinders are not abundant. Volcanic ash possesses some natural pozzolanic activity; in outcrop it is generally naturally compacted to hard but friable material. If volcanic ash was very lightly crushed to break up the larger pieces, and spread on a road surface, natural pozzolanic activity and compaction, aided by the compaction effect of traffic, might prove volcanic ash to be a suitable road surfacing agent. In areas where volcanic ash is abundant, and readily accessible, it would be worthwhile for county road departments to experiment with the material as a covering for secondary roads that bear fairly heavy traffic. It might be found that a wet application would be required or that the addition of a small amount of hydrated lime, to form a natural cement, would be desirable. It presents a possible means of improving the quality of the secondary road systems in some areas.

MINING, PROCESSING AND ECONOMIC CONSIDERATIONS

The economics of a pumicite operation are difficult to discuss because of lack of past experience. With no commercial operations in the state there are no records of costs, or values of the products for analysis.
Figure 25—Typical Flow Sheet for Calcining Pozzolan Pumice, Feed Rate 10 Tons Per Hour.

(From Klemgard, 1955)
In general, open pit mining would be used; the mining cost would vary according to the size and shape of the deposit, variations in quality of the material and the amount of overburden. Transportation costs from mine to mill or mine to railhead would be important factors as well as freight costs to market areas.

In pozzolan production, if calcining were necessary, fuel cost would be an important item that would vary with calcining temperature. Grinding and screening of the material, if required, would also be important cost items. All of the costs involved would be different for different deposits.

Klemgard (1958, p. 22) presents typical operating data for a calcining plant as follows:

- **Power:** 11.2 Kw hr (or 15 H.P. hr) per ton of pozzolan
- **Fuel:** 10 gallons Bunker C fuel oil per ton of pozzolan
- **Direct labor (operation and supervision):** five men per shift
- **Cost of direct material (raw pozzolan, delivered):** variable
- **Estimated capital investment:** $275,000
- **Feed rate:** 10 tons (20,000 lbs) per hour

As Klemgard points out, detailed basic cost data will vary with plant location and date of operation. A flow diagram of a pumicite calcining plant, with a 10 ton per hour capacity, has been adopted from Klemgard and is shown in Figure 25.

One of the basic problems preventing development of a pozzolan industry is the lack of continuous long-term markets. An operation may enjoy a guaranteed market as long as a construction project, requiring pozzolan, is in progress in the market area. However, once the project is finished, the market no longer exists and the plant is idle. Because of the investment required to establish a plant, the risk is high. Until more assured markets are developed, pozzolan production will be only locally important for short periods.

Expanded ash is not widely marketed and most of the work done has been on an experimental basis. Very little data are available on costs or values. Cost items would be somewhat similar to those involved in a pozzolan operation, however, marketing conditions would be quite different, once markets were developed.

**ORIGIN AND OTHER FEATURES**

Pumicite, like pumice, originates with explosive volcanic activity. The theoretical conditions prevailing at the time of eruption are discussed in detail under the section dealing with the origin of pumice. Some of the frothed magma is ejected more violently than other parts and it is more finely divided; the finely divided material is deposited as pumicite. Because of its much finer size, pumicite is generally deposited
farther from the source than pumice and, depending on the prevailing wind velocity, may be deposited many miles from its source. The extensive deposits of volcanic ash of Tertiary and Pleistocene age found in Oklahoma are thought to be derived from volcanoes in northwestern New Mexico (Burwell, 1949, p. 51). The depositional features and alteration characteristics of volcanic ash are similar to those of pumice. Volcanic ash alters to bentonite.

Volcanic ash is white to light gray in color generally, but light tan to buff colors are common in ash that has undergone deep weathering. The material has a gritty feel and on a weathered surface it develops a characteristic silvery sheen. The ash may be loose and powdery to firmly compacted and lithified to a volcanic tuff. Much of the ash in southern Idaho is lightly compacted and friable. Ash outcrops tend to form steep, sharp cliffs. In many instances the steep ash outcrops stand out in sharp contrast to the more gentle slopes of associated sediments. Under the microscope the powdered ash resembles a mass of minute fragments of shattered, clear glass.

Fragments of obsidian and crystalline fragments are often associated with volcanic ash, but crystal fragments are much more common in pumice because the heavier particles tend to settle out before the ash comes to rest. Fairly pure ash may be interbedded with sands and silts or between rhyolite or welded tuff flows. In many occurrences silt, sand, clay and diatomite are intimately mixed with the ash. These features vary with the depositional and post-depositional history of the ash fall.

The average composition of 6 samples of volcanic ash collected from various locations is as follows:

<table>
<thead>
<tr>
<th>Loss on ignition</th>
<th>Fe₂O₃</th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>CaO</th>
<th>MgO</th>
<th>Na₂O</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2</td>
<td>0.6</td>
<td>9.6</td>
<td>64.3</td>
<td>1.2</td>
<td>0.4</td>
<td>5.7</td>
<td>8.6</td>
</tr>
</tbody>
</table>

THE PUMICITE INDUSTRY IN IDAHO

Production and value

No data are available on the production and value of pumicite produced in Idaho. A minor amount has been used by the Idaho Portland Cement Co. at Inkom for production of portland-pozzolan cement but the tonnage and value are not known. The U.S. Bureau of Mines reports the annual tonnage and value of pumice, pumicite and volcanic cinder as one total figure and these figures cannot be broken down. It is known, however, that very little of the reported production in Idaho is pumicite.
Mining laws

The mining laws applicable to pumice are also applicable to pumicite; the laws are discussed under the section dealing with pumice.

PUMICITE DEPOSITS IN IDAHO

Pumicite - Owyhee County - Approximately Sec. 3, T3S, R2W

A deposit of volcanic ash occurs about a quarter of a mile east of the Murphy-Silver City road in Owyhee County in the Rabbit Creek drainage. The deposit is about 2 1/2 miles south of Murphy, approximately in Sec. 3, T3S, R2W.

The ash outcrops over an area about 1,000 feet long by 200 feet wide at its widest part (Fig. 26). The greatest thickness observed was 12 feet; the contact with the underlying sediments strikes north and dips about 10°E.

The ash at this locality is fairly well indurated, massive and unbedded. The material breaks into large friable pieces 2 to 3 feet across. The ash outcrops along a north-trending gully as steep cliffs; it is underlain by very fine, well indurated silt that contains shards of volcanic glass; the glass has been altered to aggregates of clay. The ash is overlain by compact sand and fine silt. The overlying material is composed of clay containing a few included quartz particles that give the rock a porphyritic appearance, and fine sand containing altered glass shards. Fragments of altered basalt are included in one of the silt beds. The fine sand outcrops east of the ash occurrence as almost vertical cliffs 20 to 30 feet high.

Indications are that the ash is lenticular. If the outcrop is followed south it can be seen to pinch down to a narrow seam less than one foot thick. Although a relatively small volume is indicated, probably in the neighborhood of 50,000 cubic yards, it is accessible and could supply a local demand. Lack of overburden over much of the exposure should facilitate mining.

A chemical analysis of the volcanic ash is shown in Table 9.

<table>
<thead>
<tr>
<th>Chemical Analysis of Volcanic Ash, Sec. 3, T3S, R2W, Owyhee County</th>
<th>(A. M. Lothe, Analyst)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>0.8</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>13.3</td>
</tr>
<tr>
<td>SiO₂</td>
<td>63.3</td>
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<td>CaO</td>
<td>1.2</td>
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<tr>
<td>MgO</td>
<td>1.0</td>
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<tr>
<td>Total Na₂O</td>
<td>6.2</td>
</tr>
<tr>
<td>Total K₂O</td>
<td>8.0</td>
</tr>
<tr>
<td>Available Na₂O</td>
<td>0.19</td>
</tr>
<tr>
<td>Available K₂O</td>
<td>0.37</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>6.1</td>
</tr>
<tr>
<td></td>
<td>99.9</td>
</tr>
</tbody>
</table>
Pumicite - Owyhee County - Sec. 35, T1S, R3W; Sec. 2, T2S, R3W

A group of hills borders the east side of the Upper Reynolds Creek road in Sec. 35, T1S, R3W and Sec. 2, T2S, R3W about 10 miles northeast of the Reynolds School. The tops of these hills are 400 to 500 feet above the valley floor. Some 80 feet of volcanic ash are exposed on the west slope of the hills; the uppermost exposure of ash is about 150 feet below the crest of the ridge. The ash outcrops can be traced continuously for about 4,000 feet along the hillside. Light-colored sand beds of the Idaho Formation underlie the ash; basalt occurs near the top of the ridge, and basalt agglomerate caps the ridge. The attitude of the sedimentary strata is about horizontal. Volcanic ash occurrences are abundant in this vicinity; other outcrops can be seen on the slopes of the next draw to the east and on the south slope of the group of hills mentioned above (Fig. 27).

The ash is friable, lightly compacted, and thin bedded. Individual beds are only 1 to 2 inches thick. An occasional thin clay bed can be seen in the ash. In the lower 60 feet of the deposit about 95 percent of the grains are fresh, clear, broken and flattened glass shards. Fluted structures are common. The remaining 5 percent consists of clay aggregates and mica flakes. A very few of the glass shards show some devitrification and included cryptocrystalline material. The upper 20 feet of the deposit is composed of about 85 percent glass and 15 percent rounded sand grains and mica flakes.

The ash beds are resistant to erosion and form steep to vertical outcrops that stand in contrast to the gentler slopes formed on the underlying sand beds. The ash is light to gray to white; a silvery sheen is developed on the exposed surface of the outcrop.

The occurrence is well situated in regard to haulage and mining.

A histogram showing the size distribution of the volcanic ash, as determined by a screen analysis, is shown in Figure 35. Much of the material retained on the larger screen sizes is because of aggregation of the particles. Most of this material would pass a 325 mesh screen, and meet the fineness requirements for pozzolanic material, with light crushing and grinding.

A chemical analysis of the ash gave the results shown in Table 10.
Figure 26 — Sketch Map Of Volcanic Ash Deposit, Approx. Sec. 3, T3S, R2W—Owyhee County.
<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>1.0</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>6.3</td>
</tr>
<tr>
<td>SiO₂</td>
<td>68.8</td>
</tr>
<tr>
<td>CaO</td>
<td>1.3</td>
</tr>
<tr>
<td>MgO</td>
<td>0.5</td>
</tr>
<tr>
<td>Total Na₂O</td>
<td>6.2</td>
</tr>
<tr>
<td>Total K₂O</td>
<td>7.6</td>
</tr>
<tr>
<td>Available Na₂O</td>
<td>0.20</td>
</tr>
<tr>
<td>Available K₂O</td>
<td>0.34</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>7.3</td>
</tr>
</tbody>
</table>

The chemical analysis indicates that the material meets the detailed specifications of the chemical composition for pozzolan as established by the U. S. Bureau of Reclamation.

On the flat valley floor just west of the volcanic ash deposit in the SW1/4 Sec. 35, T1S, R3W, several bulldozer cuts expose a thin layer of rock that could be quarried and used as decorative building stone. It appears to be a sandstone with inclusions of agate. The stone occurs in an alluvial covered area with low relief so the extent of the deposit was not determined.

Several pits and prospects have been excavated in a mass of white to gray rhyolite tuff in Secs. 26, 27, T1S, R3W (Fig. 27). The rock excavated from the pits has been sold as a soil conditioner after being finely crushed (Powers, 1955a). The mine was inactive at the time of the visit. A base for a crushing plant is on the property but the crushing equipment has been removed. The largest pit is in the SW1/4 Sec. 26, T1S, R3W near the line between sections 26 and 35. The pit is about 0.3 mile west of the Upper Reynolds Creek road.

The rock from the quarry is hard and tough. It appears to be composed of glass with aggregates of quartz distributed through the groundmass. A few small muscovite flakes can also be detected. The rock is white in color with a low specific gravity. The glass is somewhat altered and devitrified. Angular fragments of rhyolite are found in the glass but they are not abundant. The occurrence may represent a portion of a welded ash flow.
Along Squaw Creek, just south of French John Hill, on U. S. Highway 95, a series of clay-volcanic ash beds occur. The chief exposures are in sections 25 and 26, T1N, RSW but beds of volcanic ash can also be seen in sections 24, 35 and 36, T1N, RSW (Fig. 28). The beds are thought to be members of the Payette Formation of Miocene age.

The sediments are capped by rhyolitic flow rocks that are exposed on either side of the valley of Squaw Creek. Northwest of Highway 95, above the exposures of silt and ash, the rhyolite forms near vertical cliffs. A generalized section through the sediments from the base of the cliffs to Squaw Creek reveals a series of alternating clay and ash beds about 350 feet thick; all of the beds contain fragments of pumice in greater or lesser amounts and in several units pumice is an important constituent of the rock. All of the pumice fragments observed are altered to soft, clay-like masses that disintegrate in water. Volcanic glass is also distributed completely through the series; all of the clay beds examined contain shards of volcanic glass showing varying degrees of alteration. Some of the clay present was probably derived from contained volcanic ash and pumice but most of the clay was deposited as fine silt. The beds of volcanic ash contain some silt and pumice, but the dominant constituent is volcanic glass. Much of the glass, particularly in the thicker beds, is devitrified and partially altered to clay, but beds of ash showing only slight alteration and devitrification are present. The following is a generalized geologic section through the series that reveals the sequence of alternating clay and ash units. The beds vary from 3 feet to 120 feet in thickness.

General section through volcanic ash - tuffaceous clay sequence in Payette Formation; Secs. 25 and 26, T1N, RSW, Owyhee County.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Description</th>
<th>Thickness in feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yellowish clay with altered pumice fragments; mass, including pumice, disintegrates in water</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>Gray volcanic ash; compact, coarse, friable; glass shards somewhat devitrified. Contact at base about horizontal</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Yellow-orange, sandy clay, with highly altered pumice fragments, similar to sample 1 above</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>Gray volcanic ash, fairly pure, glass shards only slightly altered</td>
<td>4</td>
</tr>
</tbody>
</table>
Figure 27—Location Map of Volcanic Ash Deposits, Reynolds Road, Sec. 35, T1S, R3W; Sec. 2, T2S, R3W, Owyhee County.

Contours 200 ft. with 40 ft. interval near ash deposits.
(Base from U.S.G.S. Wilson Peak Quadrangle, Idaho.)
Yellowish brown clay; contains water-worn pebbles, mostly rhyolitic, 2 inches to 3 inches across; clay disintegrates in water rapidly; some relict pumice structure evident

Compact, dark gray volcanic ash with pumice particles and minor water-worn pebbles. Pumice particles altered to clay. Glass devitrified. Pumice particles disintegrate in water

Light gray volcanic ash, upper 3 feet coarse grained pumiceous; consists of pumice particles in matrix of ash with clay coatings on the glass shards; pumice particles are soft, altered to clay; glass shards devitrified. Mass compact but crumbles easily. Lower 48 feet finer grained, compact mass of coarse volcanic glass shards that are devitrified. Contains several 1 inch to 6 inch lenses of coarse pumiceous material. Strikes N70E, dips 15°N.

Brown clay with minor pumice that is highly altered; possibly clay is from alteration of volcanic glass, shard-like structures evident

Volcanic ash with pumice fragments. Strikes N40E, dips 22°N.

Light brown, sandy clay; hard, indurated; minor minute glass shards and clay aggregates

Light gray volcanic ash

Brownish-orange clay; resembles sample No. 8

Pumiceous volcanic ash, coarse to fine, altered

Yellow clay; lower 20 feet contains pumice fragments; pieces of soft pumice and glass are mixed with clay

Mixed volcanic ash and altered pumice. Ash is coarse, gray, devitrified and altered. Pumice fragments are highly altered, soft. Forms massive layer on valley floor at Squaw Creek.
An interbedded vesicular basalt flow is exposed near the west 1/4 corner of Sec. 25. Several pits and trenches expose this rock; opal is found in the vesicles of the basalt.

The sediments appear to be highly lenticular and tend to pinch out in short distances laterally. Alluvial cover is heavy and most of the beds cannot be followed more than 300 feet before they are obscured by alluvium, or they pinch out. In some instances they are faulted off by small normal faults that cut the sedimentary sequence. On the southeast side of Squaw Creek the beds making up the sequence are exposed on a steep bluff. The lenticular nature of the ash and pumice beds can be readily observed along the bluff; as the beds are followed laterally they pinch out abruptly or end against a fault contact.

Dips and strikes in the sequence of sediments are variable. In general, in the upper 50 feet of the sequence, the beds are about horizontal. In the lower part they strike N40°-70°E and dip 15 to 25°N.

On the southeast side of U. S. 95, in the southeast corner of Sec. 24, T1N, R5W, a bed of relatively pure ash, about 30 feet thick, crops out. It can be traced laterally for about 300 feet. Figure 29 is a photograph showing a close-up view of the ash outcrop. Farther south in Secs. 34 and 35 thin beds of ash can also be observed along the highway (Fig. 28).

Lack of adequate base maps and extensive overburden prevent an estimate of the volume of material present at this locality. Structural variations, because of faulting, the lenticular nature of the sediments and possible cross-bedding further complicate the picture.

Volcanic ash and pumiceous ash are distributed over a large area; several of the beds are of mineable thickness and favorably situated for extraction, but the lenticular nature of the material indicates that this locality is of little importance. Detailed mapping, in conjunction with trenching or other means of exposing the sedimentary units, could possibly disclose a large volume of mineable material. Further prospecting in the general area might also disclose more suitable occurrences of pumice and ash, however, in the course of this reconnaissance study it appeared that the beds are too lenticular, and the material too highly altered, to warrant further investigation.

**Pumice - Owyhee County - Bruneau and vicinity**

Near the township and range marker between T8S, R5E and T7S, R4E, about 11 miles south of Bruneau, on the west side of State Highway 51, there are several beds of volcanic ash interbedded in sands and silts of the Idaho Formation (No. 1, Fig. 32). The beds are from 5 to 10 feet thick; they are flat lying. Although the ash beds are extensive they are too thin, and would be too difficult to extract, to be of economic significance.
Figure 28 - Map Of Volcanic Ash Occurrence, Sec. 25, 26, T1N, R5W; Squaw Creek, Owyhee County.
Fig. 29. Photograph of volcanic ash outcrop; Sec. 24, T1N, R5W, Owyhee County. Fault cuts outcrop on right side of picture.

Fig. 30. Photograph of volcanic ash deposit showing typical appearance when viewed from a distance. Taken near Bruneau, Owyhee County. (Photo by J. Peebles)

Fig. 31. Close-up view of volcanic ash outcrop shown in Figure 30. (Photo by J. Peebles)
Similar exposures occur in the foothills on the east side of State Highway 51 about one mile farther south (No. 2, Fig. 32). An excavation has been made at the base of one of the ash beds to expose an underlying sand carrying good specimens of fossil wood and other fossils. Several pieces of pumice were seen on the hillside at this locality as loose debris, but no pumice outcrops were found.

The volcanic ash is fine grained and contains only minor amounts of sand, silt or other sedimentary material. The shards of glass are small, flattened and pitted.

Thin beds of ash can also be seen at several places near Bruneau. A 10-foot bed of ash crops out along Buckaroo Ditch, southeast of Bruneau, as steep cliffs along the canal (No. 3, Fig. 32).

Ash, sand and pumice occur west of this locality in Secs. 9, 10, and 11, T8S, R4E; beds are 10 to 20 feet thick and horizontal (J. J. Peebles, April, 1963, written communication). This locality was not visited during this investigation.

Figure 30 is a photo of a typical volcanic ash outcrop viewed from a distance. Figure 31 is a close-up view of the same occurrence.

Pumice - Owyhee County - Bruneau-Grandview area

Beds of the Idaho Formation outcrop extensively between Bruneau and Grandview; they are composed of light-colored, white to buff sand and silt. Thin beds of volcanic ash, from 3 to 10 feet thick, can be seen at several places interbedded in the other sediments, but no deposits of commercial interest were noted. Ash beds are well exposed in Little Valley southwest of Bruneau (No. 4, Fig. 32) along Jacks Creek (No. 5, Fig. 32), in the Chalk Hills (No. 6, Fig. 32), and in the vicinity of Shoo fly road and Shoo fly Creek (No. 7, Fig. 32).

Near State Highway 51, just south of Grandview, clayey beds of the Idaho Formation are mined from a small pit and used locally as a ditch-lining material (No. 8, Fig. 32). The material is a mixture of clay, volcanic ash and diatomite; the volcanic glass particles are somewhat altered. The mixture is very fine grained and powdery; it is white in color. When placed in water the material slakes to an aggregate of flat scales.

On the road south of Oreana, between Brown Creek and Castle Creek, there are extensive exposures of fine, powdery sand; it is well exposed in Secs. 5 and 6, T5S, R1E (No. 9, Fig. 32). This sand supports little vegetation and shows a badland type topography; it is white to gray in color and appears to be a fine dust composed of quartz grains and clay aggregates. It is possible that this material represents weathered volcanic ash; a 6-inch bed of light gray, fresh volcanic ash is interbedded in this material.
Tuffaceous clay - Owyhee County - Secs. 4, 9, T7S, R3E

An extensive deposit of fine, powdery, yellowish-brown clay occurs in Secs. 4 and 9, T7S, R3E on Shoo fly Creek (No. 10, Fig. 32).

The deposit appears to be an extremely fine-grained mixture of volcanic ash, gypsum, clay, quartz grains and other sedimentary materials. Gypsum is abundant; it is scattered loosely throughout the deposit as large fibrous aggregates and small fragments. This sandy clay is very similar in appearance to the material that mantles the surface at the Ben-Jel bentonite property some 15 miles northwest. In addition to the loose, lightly compacted powder, a bed of hard, indurated mixed clay, gypsum and diatomite occurs. In composition it is similar to the material used for ditch lining material near Grandview; in appearance it resembles the Ben-Jel bentonite, but it does not swell in water.

Several bulldozer cuts and trenches exist on the property. At the time of this examination the ground was claimed by Calvin Carothers of Grandview.

The similarity of this deposit to the Ben-Jel bentonite deposit suggests that bentonite may underlie the clay, or occur nearby, although none could be found.

Pumicite - Twin Falls County - Buhl, Castleford and vicinity

Local residents report that volcanic ash and pumice occur near Buhl and Castleford and also in the valley of Salmon Falls Creek. No deposits of material suitable for volcanic construction materials were seen during a brief reconnaissance of this region; however, careful prospecting might reveal such deposits in the area because pyroclastic material, mostly welded tuff, is widespread.

Pumicite - Twin Falls, Cassia counties - Cassia Mountains

A reconnaissance trip across the Cassia Mountains, from Rogerson on the west to Oakley on the east, was undertaken to check the possibility of pumice and volcanic ash occurring in association with the welded tuffs and acidic extrusives capping many of the ridges and peaks of the mountains. In addition, volcanic ash is reported to occur near the heads of Deep, Cottonwood, McMullen and Dry creeks on the north flank of the range (Stearns and others, 1938, p. 40). These localities were checked in conjunction with the general reconnaissance of the mountains but no deposits of volcanic construction materials were found. Figure 33 is a generalized location map of the Cassia Mountains taken from Youngquist and Haegle (1956).

No detailed prospecting was done because the region is remote and not easily accessible. Such conditions would not permit an economically successful
Figure 32 - Location Map Of Volcanic Ash Deposits, Bruneau - Grandview Area, Owyhee County.
operation based on a low unit value material like pumice or pumicite.

A few small occurrences of ash can be seen in the draws and canyons that cut the western flank of the mountains; one such locality is in the canyon of Goat Springs Creek in T13S, R17E (No. 1, Fig. 33). A few small, isolated lenses of ash were noted at this locality. Further prospecting in the canyons and gullies on both the western and northern margins of the mountains might reveal appreciable volumes of ash.

The ash from Goat Springs Creek is very fine and relatively pure; a few small, rounded pieces of black obsidian are included in it. A chemical analysis of the sample is presented in Table 11.

<table>
<thead>
<tr>
<th>TABLE 11 - Chemical analysis of volcanic ash, T13S, R17E, Twin Falls County, (A. M. Lothe, Analyst)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
</tr>
<tr>
<td>Al₂O₃</td>
</tr>
<tr>
<td>SiO₂</td>
</tr>
<tr>
<td>CaO</td>
</tr>
<tr>
<td>MgO</td>
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<tr>
<td>Total Na₂O</td>
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<tr>
<td>Total K₂O</td>
</tr>
<tr>
<td>Available Na₂O</td>
</tr>
<tr>
<td>Available K₂O</td>
</tr>
<tr>
<td>Loss on ignition</td>
</tr>
</tbody>
</table>

This volcanic ash contains less silica and more alumina than most of the other samples analysed for this report.

Pumicite - Twin Falls County, Rock Creek

Rhyolitic rocks are exposed in the valley of Rock Creek in northeastern Twin Falls County and western Cassia County on the northern flank of the Cassia Mountains. At several places along Rock Creek exposures of volcanic ash can be seen interbedded in the surrounding rhyolitic extrusives. In general, the limited outcrop area of these deposits does not exhibit a large available tonnage and the surrounding rhyolites would present troublesome mining problems. A rather complete reconnaissance of the lower part of Rock Creek was made in connection with this investigation but no large deposits of ash were found. It is likely that there are similar occurrences of ash in other valleys on the flanks of the range and it is possible that mineable deposits could be found if careful prospecting were done.
An occurrence of volcanic ash is located on the steep eastern slope of the stream valley in the SW1/4 Sec. 12, T12S, R18E (Locality 2, Fig. 33). Tuffaceous beds are exposed through a thickness of about 150 feet below a cap of silicic extrusive rocks. The deposit consists of rather pure, fine to coarse volcanic ash beds, interbedded with sandy ash. The material is light gray to white except near the top of the exposure where a 15-foot bed of light-brown to tan, sandy tuff can be seen. The beds dip about 15 degrees east, into the hillside; near the base of the exposure cross-bedding is evident. From the base of the beds, west, and downslope, the hillside is covered for about 25 feet, to the floor of Rock Creek valley. At the top, the beds are in contact with rhyolitic rocks; at the contact a thin band of dark glass separates the sediments and flow rocks. The flow rocks form cliffs that reach several hundred feet above the top of the ash exposure.

The beds of ash and ashy sand strike north to northwest; they can be traced laterally for about 200 feet along the slope of the hill. The rhyolitic rocks extend gradually downslope and reach the valley floor about 500 feet north of the outcrop and 500 feet south of the outcrop. The intervening ground, between the ash and rhyolite exposures, is covered by soil and vegetation.

It appears that this deposit is a lens of ash and sand deposited in a local basin and later covered by rhyolitic flows. Even if the ash is continuous along strike it would extend under a rhyolite cover in a short distance.

In order to gain an idea of the composition of the volcanic ash occurring in the vicinity of Rock Creek a chemical analysis (Table 12) was made from samples taken at the occurrence just described.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
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</tr>
<tr>
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<td>CaO</td>
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<td>Total K₂O</td>
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<td>Available K₂O</td>
<td>0.51</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>6.2</td>
</tr>
</tbody>
</table>

TABLE 12 — Chemical analysis of volcanic ash SW1/4, Sec. 12, T12S, R18E, Twin Falls County, (A. M. Lothe, Analyst)
In approximately the SE1/4 Sec. 36, T12S, R18E there is an exposure of volcanic ash and an interbedded rhyolite flow. The outcrop is northeast of the road (Locality 3, Fig. 33).

Near the base of the exposure there are 10 feet of ash striking N60E and dipping 10°NW. The ash beds have been offset by a small, vertical, north-trending fault with a displacement of about 3 feet. The ash is overlain by about 25 feet of fairly coarse sand followed by 12 to 15 feet of hard tuffaceous material. Six feet of sandy tuff overlies this hard indurated material. Glassy rhyolite or welded tuff, about 100 feet thick, containing many thin bands of obsidian, overlies the sandy tuff. The rhyolite is overlain by about 30 feet of relatively pure ash with two feet of sand at the base of the exposure. Fifteen feet of sandy ash overlies the relatively pure ash. The uppermost part of the sandy section is concealed to the base of the cliffs of acidic extrusives which flank Rock Creek. The ash and sand are exposed for about 1,000 feet south of the section described, by intermittent outcrops.

The ash in the 30-foot bed overlying the rhyolitic flow is fairly typical, gray ash, but many of the glass shards are coated by a yellowish alteration product, probably clay, that occurs in bands or streaks through the outcrop.

The steep slopes along Rock Creek, the interbedded sand and the interbedded rhyolitic material make this occurrence of doubtful value. The upper bed, about 30 feet thick, might be subject to development and provide a sustained production for a small-scale operation. However, mining costs, especially overburden removal, would probably be excessive.

On the west side of Rock Creek in the SW1/4 Sec. 20, T13S, R19E, there is an outcrop of relatively pure ash which forms a near-vertical cliff along the stream bank (Locality 4, Fig. 33). The ash appears to be about 50 feet thick; it strikes north and outcrops for about 150 feet along the stream. The material is rudely bedded; locally dips are variable, but as a whole the beds dip west, into the hillside, at about 15°. Near the top of the outcrop sandy ash is predominant; rhyolitic rocks cap the outcrop.

Several hundred feet farther south, across a shallow draw, ash and sandy ash can be seen capping several small knolls; the ash is underlain by rhyolite. These beds strike N65E and dip 17°N. It appears that the material to the south is separated in vertical section from the more northerly exposure by a rhyolite flow. The two outcrops probably represent different periods of sand and ash accumulation during times of quiescence in volcanic activity.

It is not likely that a large tonnage of material could be economically developed at this locality. Intermixed sand, excessive overburden, and the lenticular nature of the ash deposits would be prohibitive.
Small lenses of ash can be seen at irregular intervals along the west side of Rock Creek for about 1/2 mile south of the above locality.

**Pumicite - Cassia County-Goose Creek Basin**

A large part of the Goose Creek Basin in southern Cassia County is made of a series of so-called "lake beds" and intercalated and capping rhyolite flows of late Miocene age. Anderson (1931) correlates similar beds of ash and sediments that occur in the eastern part of Cassia County, with the Salt Lake and Payette formations. The "lake beds" are chiefly volcanic ash and clay; they crop out extensively south and west of Oakley (Fig. 34).

The geology of Goose Creek Basin has been described by Piper (1923); the following discussion is adopted from his work. Bowen (1913) also briefly discusses the geology of this area.

The late Miocene series under discussion is exposed in T12S, T23E; T13S, R21E; 22E; and 23E; T15S, R19E, 21E, and 22E, and T16S, R19E, 20E, 21E and 22E. An upfaulted block of this series, capped by rhyolite, is exposed in a belt 1 to 3 miles wide in Tps. 13 and 14S, near the line between R22E and 23E, east of Oakley. At places, particularly southwest of Oakley, the continuity of the outcrop area is interrupted by isolated outcrops of Paleozoic rocks (Fig. 34).

Thick beds of volcanic ash make up a large part of the late Miocene series, but in many places the capping rhyolite conceals the underlying ash. The ash, however, is well exposed in many of the stream valleys tributary to Goose Creek where the rhyolite has been removed by erosion. Probably the best exposures are along Trapper Creek west of Oakley and in the upper part of Goose Creek near the Idaho-Utah boundary south of Oakley. Beds of this series are also exposed south of the state line in Utah and Nevada.

According to Piper (1923, p. 28) the maximum thickness of the late Miocene rocks in the area is about 1,700 feet as exposed along Trapper Creek. Outcrops of stratified volcanic ash up to 410 feet thick have been measured along this stream.

The following generalized composite section, taken from Piper (1923, p. 28), along Trapper Creek brings out the relations between the different members of the series:
Figure 33 - Location Map, Pumicite Deposits, Cassia Mountains And Vicinity.
<table>
<thead>
<tr>
<th>Member</th>
<th>Depth</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Rhyolite cap rock; thin, sheeted and bluish gray at top, grading into dense red-brown at bottom</td>
<td>0-101</td>
<td>101</td>
</tr>
<tr>
<td>2 Volcanic ash or &quot;lake beds&quot;, gray to white, bedded, friable</td>
<td>101-113</td>
<td>12</td>
</tr>
<tr>
<td>3 Rhyolite</td>
<td>113-228</td>
<td>115</td>
</tr>
<tr>
<td>4 Volcanic ash, gray to white, stratified, locally cross-bedded, poorly consolidated</td>
<td>228-360</td>
<td>132</td>
</tr>
<tr>
<td>5 Rhyolite</td>
<td>360-388</td>
<td>28</td>
</tr>
<tr>
<td>6 Volcanic ash showing local crossbedding. One bed of buff sandy clay grading downward into typical ash</td>
<td>388-508</td>
<td>120</td>
</tr>
<tr>
<td>7 Rhyolite</td>
<td>508-576</td>
<td>68</td>
</tr>
<tr>
<td>8 Volcanic ash beds, outcrops masked by talus</td>
<td>576-986</td>
<td>410</td>
</tr>
<tr>
<td>9 Rhyolite</td>
<td>986-1042</td>
<td>56</td>
</tr>
<tr>
<td>10 Volcanic ash, gray, coarse</td>
<td>1042-1071</td>
<td>29</td>
</tr>
<tr>
<td>11 Lignite and alternating fine white clays, some intercalated ash, five lignite beds 0.2 to 1.0 foot thick</td>
<td>1071-1101</td>
<td>30</td>
</tr>
<tr>
<td>12 Two strata of fine white clay grading downward into typical volcanic ash</td>
<td>1101-1356</td>
<td>255</td>
</tr>
<tr>
<td>13 Lignite, enclosed by fine white clay</td>
<td>1356-1358</td>
<td>2</td>
</tr>
<tr>
<td>14 Volcanic ash, clay, sandy clay, and ashy sandstone</td>
<td>1358-1590</td>
<td>232</td>
</tr>
</tbody>
</table>
Dense white to blue clay, several intercalated streaks of carbonaceous shale 1590-1597 7
Conglomerate, loosely consolidated, Pebbles of limestone, chert and quartzite 1597-1601 4
Fine sandy clay, argillaceous ash, fine blue shale and typical volcanic ash interbedded 1601-1613 12
Conglomerate, sandy at top, Pebbles of limestone, chert and quartzite 1613-1625 12
Volcanic ash, with some intercalated argillaceous beds, to bottom of exposed section 1625-1700 75±

As pointed out by Piper (1923, p. 28) it is apparent that the late Miocene series can be divided into two parts: an upper part consisting of rhyolite flows and intercalated volcanic ash beds, and a lower part consisting of volcanic ash with intercalated sedimentary material. The division falls at Unit 9 on the composite section. The two parts represent periods of differing intensity of igneous activity. The characteristics of the ash in the two parts are similar.

Generally the bases of the rhyolite flows are marked by a band of dark glassy obsidian followed by highly vesicular rhyolite grading upward into dense felsitic rhyolite. The five flows indicated in the generalized section are similar in composition but a wide variety of textures are evident reflecting differences in the rate of cooling at different places. In general the textures seen in the rhyolite are indicative of rapid cooling.

The volcanic ash is light gray to white in color, fine to coarse grained and poorly consolidated. The ash is bedded and friable, locally cross-bedding can be observed. Interbedded in the ash, especially in the lower or older part, are beds of fine white clay, buff sandy clay, ashly sandstone and thin shaly beds. All of these interbedded units contain volcanic ash to some degree. Lignite seams and streaks of other carbonaceous material occur in association with some of the clay beds. Near the base of the series, conglomerates, composed of pebbles of chert, limestone and quartzite, occur. The interbedded sediments are poorly consolidated.

According to Piper (1923, p. 40-41) in middle Tertiary time a period of volcanism began with the extrusion of massive rhyolite flows now exposed south of the Idaho boundary in Utah along Bluff Creek and Spring Creek. Next came a period of quiescence and the development of an erosion surface was begun. Later, probably in late Miocene time, came the accumulation of sediments and acid ejecta. Near the end of the epoch there was intense igneous activity and heavy flows followed one another in
rapid succession.

It is likely that the ash and sediments accumulated in a ponded environment consisting of strings of short-lived ponds and wandering streams. The rapid accumulation of large amounts of volcanic debris probably choked existing drainage channels and gave rise to the development of ponded conditions. Sedimentation in the ponds and stratification of the volcanic ash by winds and torrential rains formed the bedded deposits now exposed in the basin.

The late Miocene series has mildly complicated structure. The beds have been arched and gently folded into an anticline; the fold axis trends east-west about parallel to Trapper Creek. Normal faults, with the downthrown block to the west, offset the late Miocene rocks at many places in the basin. The ash beds dip gently, 5° to 15° to the north, south and east (Fig. 34).

The following section, taken from Bowen (1913, p. 255) is an example of a typical exposure through a portion of the series and shows the character of the strata. The section was measured in the NE1/4 Sec. 33, T16S, R21E, just north of the state line near the confluence of Beaverdam Creek and Goose Creek.

Section of late Miocene rocks, NE1/4 Sec. 33, T16S, R21E, Cassia County (from Bowen, 1913)

<table>
<thead>
<tr>
<th></th>
<th>Ft.</th>
<th>In.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhyolite, pink, dense; to top of butte</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Rhyolite, cellular, with spherulites</td>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>Obsidian, black</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>Sandstone, black, indurated, becoming gradually harder toward top</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Volcanic ash, gray</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Sandstone, conglomeratic, with pebbles of obsidian and indurated sandstone</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>Volcanic ash, gray</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>Sandstone, yellow, coarse, gritty, with rounded grains</td>
<td>1</td>
<td>6</td>
</tr>
</tbody>
</table>
Volcanic ash  83  -  
Clay, sandy  2  6  
Volcanic ash  12  -  
Sandstone, red, indurated  1  3  
Obsidian  1  3  
Sandstone, indurated  1  3  
Volcanic ash, white to gray, with intercalated beds of sandy clay  175  -  
Talus to bottom of hill  

408  9

The section was taken on the slope of a ridge on the northeast side of Beaver-dam Creek. The slope is gently and an ash bed could be easily mined; for example, the 175-foot ash bed near the valley floor could be extracted with little difficulty or over-burden removal. The valleys of the larger streams in the basin, where they have cut through the overlying rhyolites into the easily erodible sedimentary beds, are wide, and the slopes on either side are gentle; a large quantity of volcanic ash is exposed on the slopes of the valleys. The ridge tops are characterized by rim-rocks and flat, mesa-like tops. Because of the wide valleys and gentle slopes a great quantity of volcanic ash exists that is accessible and easily mineable. The deposits are near rail transportation, a branch of the Union Pacific Railroad extends to Oakley. Should a sustained need for volcanic ash arise there are sufficient reserves in the Goose Creek basin to supply a large demand for a number of years.

Samples of volcanic ash in the Goose Creek Basin were taken at several localities. On the south side of Trapper Creek, in Sec. 15, T15S, R20E, a series of samples were taken through 300 feet of volcanic ash. The samples show that the ash contains very little admixed sand and silt and it is little altered; it is poorly consolidated and friable and it is fine grained. A few thin beds of clayey ash and ashy shale are interbedded, but these constitute no more than 10 percent of the total section sampled. Examinations at other localities in the area, where thick sequences of volcanic ash are exposed, and samples taken from these localities, gave similar results.

Figures 36, 37 and 38 give the results of screen analyses of material sampled through 300 feet on the south side of Trapper Creek. Figure 36 represents the material from the upper 100 feet of the deposit and Figure 37 represents the lower 200 feet. The upper 100 feet contains no interbedded sand or clay layers; the lower 200 feet contains several thin beds of clay and ashy shale; proportionate amounts of these interbeds were included in the volcanic ash sample. Figure 38 shows the size distribution of the entire 300-foot sampled section, as calculated from the results of the analyses of the upper and lower portions.
Figure 34 - Geologic Map Of Goose Creek Basin, Cassia County.
Fig. 35. Histogram showing size distribution of volcanic ash; Sec. 35, T1S, R3W, Owyhee County.

Fig. 36. Histogram showing size distribution of volcanic ash; Upper 100 feet of a 300 foot sampled section. South side of Trapper Creek, Sec. 15, T15S, R20E, Cassia County.
Fig. 37. Histogram showing size distribution of volcanic ash; lower 200 feet of a 300 foot sampled section. South side of Trapper Creek, Sec. 15, T15S, R20E, Cassia County.

Fig. 38. Histogram showing size distribution of volcanic ash, 300 foot section south side of Trapper Creek, Sec. 15, T15S, R20E, Cassia County (calculated from analyses of upper 100 feet and lower 200 feet).
Many of the particles retained on the larger screens, particularly in the lower 200 feet, consisted of aggregates of volcanic glass shards that would be broken into individual fragments during handling in a mining operation, because of the friability of the material; thus the separation of fines would be increased. In this respect the screen analyses are somewhat misleading. However, on the basis of the results of the screen analyses, light crushing would be required to produce a product of the fineness required for pozzolans; the U. S. Bureau of Reclamation specifies that not more than 12 percent of the material be retained on a 325-mesh screen.

Chemical analyses of the volcanic ash from the Goose Creek Basin shows that it meets the requirements for chemical composition of pozzolans specified by the U. S. Bureau of Reclamation. The chemical composition of a composite sample from the area is given in Table 13.

**TABLE 13 - Chemical analysis of volcanic ash, Goose Creek Basin, Cassia County, (A. M. Lothe, Analyst)**

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>0.2</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>7.4</td>
</tr>
<tr>
<td>SiO₂</td>
<td>70.3</td>
</tr>
<tr>
<td>CaO</td>
<td>0.7</td>
</tr>
<tr>
<td>MgO</td>
<td>0.1</td>
</tr>
<tr>
<td>Total Na₂O</td>
<td>4.7</td>
</tr>
<tr>
<td>Total K₂O</td>
<td>9.0</td>
</tr>
<tr>
<td>Available Na₂O</td>
<td>0.17</td>
</tr>
<tr>
<td>Available K₂O</td>
<td>0.51</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>6.4</td>
</tr>
</tbody>
</table>

**Pumicite - Cassia County - Secs. 13, 24, T16S, R24E**

About 5 miles south of Almo a group of low hills rises above the alluvial-filled Almo basin. These hills cover an area of about 2 square miles in Secs. 13 and 24, T16S, R24E (Locality 2, Fig. 40). The hills slope gently west; a well-defined, north-trending ridge separates them from the alluvial covered plain to the east. The ridge is capped by glassy rhyolite with a 2-foot band of obsidian at the base of the flow. The rhyolite has been eroded off the western slope of the ridge and a steep, west-facing scarp has formed in the central part of the ridge. A thin bed of sandstone followed by 50 feet of volcanic ash is exposed on the face of the scarp. The ash is also underlain by sandstone. Hill wash and alluvium prevent tracing the ash bed for more than 200 to 300 feet but it probably extends along the entire margin of the hillslope. Figure 39 is a geologic sketch of the occurrence.
The group of hills appears to represent an upfaulted block of Tertiary lavas and sediments lying along the southern extension of a fault paralleling the west base of the Malta Range farther north (Fig. 40).

The deposit is accessible and adaptable to open-pit mining, however, the locality is remote from transportation. The ash from the deposit contains 15 to 25 percent admixed silt, and sand. The ash shows little alteration and devitrification, although the shards are broken and somewhat flattened.

**Pumicite - Cassia County - Sublett and Black Pine ranges**

A reconnaissance through the Sublett and Black Pine ranges revealed very little volcanic ash. Much of the area in the lower foothills is under cultivation and there are few exposures. A small outcrop was noted on the east side of South Heglar Canyon in a cultivated field. The ash was exposed through approximately 30 feet but could not be traced laterally. About 1,000 feet north of the Meadow Creek road, approximately in Sec. 4, T14S, R23E, near the north end of the Black Pine Range, a 6-foot bed of ash is exposed in a small pit. The ash is overlain by rhyolite and alluvium and does not appear to be extensive.

According to Anderson (1931, p. 40) there is a great deal of ash in parts of the Sublett Range and in the valley between it and the Black Pine Range. Very little ash was seen during a brief reconnaissance of the region, but further prospecting might reveal significant amounts. Anderson’s geologic map shows extensive exposures of Payette or Salt Lake Formation in the region, and large quantities of volcanic ash are associated with these units at other places (Fig. 40).

**Pumicite - Cassia County - Malta Range**

The Malta Range is a tilted fault block located between Malta on the east and Elba on the west. The Raft River flows around the south end of the range and parallels its east flank (Fig. 40). The range is made up of Tertiary sediments of the Payette or Salt Lake Formation and capping lava flows. The sediments are chiefly tuff or volcanic ash; however, they are largely concealed by the capping lava flows and talus and alluvium on the flanks of the range.

On the east, the sediments, mostly volcanic ash, are thick but poorly exposed because of landslide blocks consisting of the capping lava. No samples were taken on the east side of the range. Thick sequences of mineable ash occur, however, that could be developed.

On the west flank of the range a few small outcrops of ash occur between Albion and Elba; they are exposed at the heads of several gullies that have cut through the overlying lavas and alluvium. Exposures are too poor to estimate the quantity of ash available but a large volume is undoubtedly present. Mining would be somewhat
Figure 39—Geologic Sketch Map And Section, Volcanic Ash Occurrence, Sec.13, T16S, R24E; Almo Basin, Cassia County.
Figure 40 - Generalized Geologic Map Of The Malta Range And Vicinity, Cassia County.
difficult as slopes are steep. There is a small quarry developed about 7 miles east of Albion in volcanic tuff. The material from this quarry was formerly used as a building stone (Anderson, 1931, p. 145).

At the south end of the Malta Range approximately in Sec. 26, T15S, R25E, an outcrop of volcanic ash is well exposed (No. 1, Fig. 40). The outcrop is capped by massive rhyolite flows followed by 450 feet of friable volcanic ash. The upper 150 feet is made up of bedded volcanic ash containing a few beds of sand 1 foot to 2 feet thick; angular chert fragments occur in some of the sand beds. A 10-foot bed of hard, indurated tuff, composed of clay aggregates, volcanic glass shards and minor diatoms, follows the 150 feet of ash. Below the tuff there is another 300 feet of volcanic ash similar to the upper 150 feet. Near the bottom of the series a second bed of hard tuff is exposed; its thickness was not determined because its base is not exposed.

There are over 400 feet of mineable ash exposed in this outcrop; intermittent exposures can be seen to the east for about 7 more miles along the southern flank of the range that are probably continuous with the outcrop discussed above.

The volcanic ash exposed at the south end of the Malta Range is fairly hard, firm and well indurated, however, the individual shards of glass are small. There are thin beds, 1 to 2 inches thick, of coarser glass interbedded in the fine ash. The coarser beds show numerous pellets of dark volcanic glass about the size of coarse sand. That the material making up the deposit is well indurated is shown by the histogram in Figure 42; it represents a screen analysis of a sample through the upper 150 feet of the deposit. Approximately 60 percent of the ash was retained on a 1/2-inch screen. This material represents firmly indurated and agglomerated particles of volcanic ash. The remaining 40 percent was distributed fairly uniformly through the remaining size intervals with a concentration of fines at minus 325 mesh (0.0017 inch). This remaining 40 percent represents material that was disaggregated by sampling and subsequent handling; extraction and normal handling would increase the fines in a product but light crushing would probably be required to produce a 325 mesh product. The screen analysis was made on natural material with no preparatory crushing or grinding.
TABLE 14 - Chemical analysis of volcanic ash - south end of Malta Range, Sec. 26, T15S, R25E, Cassia County
(A. M. Lothe, Analyst)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>0.6</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>14.8</td>
</tr>
<tr>
<td>SiO₂</td>
<td>63.4</td>
</tr>
<tr>
<td>CaO</td>
<td>1.2</td>
</tr>
<tr>
<td>MgO</td>
<td>0.2</td>
</tr>
<tr>
<td>Total Na₂O</td>
<td>6.2</td>
</tr>
<tr>
<td>Total K₂O</td>
<td>6.6</td>
</tr>
<tr>
<td>Available Na₂O</td>
<td>0.25</td>
</tr>
<tr>
<td>Available K₂O</td>
<td>0.54</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>6.9</td>
</tr>
</tbody>
</table>

Pumicite - Blaine County - Secs. 31, 32, T18S, R21E

A deposit of volcanic ash occurs just south of State Highway 23 between Carey and Picabo in Blaine County. The occurrence is slightly north of the southwest corner of Sec. 31 on the line between Sec. 31 and 32, T18S, R21E. Sandstone, tuffaceous sandstone and impure diatomite are interbedded with the volcanic ash, and pumice occurs nearby as well. The occurrence of ash is on the north slope of a rhyolite-capped ridge north of the confluence of Silver Creek and Little Wood River. The deposit is in the Silver Creek drainage (Fig. 41). The pumice occurrence is discussed in the pumice section of this report.

On the north side of the rhyolite-capped ridge, ash is well exposed at two locations about 1/4 mile south of Highway 23, across a wide draw. The two exposures are approximately 1,000 feet apart. At the northeast end of the ridge, there is a 6-foot bed of somewhat coarse, sandy volcanic ash that contains several thin beds of non-tuffaceous sand, overlain by about 35 feet of indurated tuff and tuffaceous sandstone containing minor diatoms. A bed of fine, fairly pure ash overlies the hard tuffaceous material. The full thickness of this upper ash bed is not exposed.

About 1,000 feet southwest of the northeast exposure also on the flank of the ridge another ash outcrop can be seen. Cover prevents tracing these beds continuously from northeast to southwest, but they are probably continuous. The tuffaceous material separating the upper and lower ash at the northeast seems to wedge out to the southwest. The fine, relatively pure ash appears to be continuous with the lower sandy ash at the more southwesterly locality. There is a probable thickness of about 85 feet of ash at the southwest end. Sandy tuff and impure diatomite underlie the ash at both exposures. In the lower sandy ash a few particles of pumice can be seen intermixed...
Figure 4: Location Map, Punicite Deposit, Sec. 31, 32, T1S, R21E, Blaine County.
Fig. 42. Histogram showing size distribution of volcanic ash, Sec. 26, T15S, R25E, Cassia County.

Fig. 43. Histogram showing size distribution of volcanic ash, Sec. 31, T1S, R21E, Blaine County.
with the sand.

An adit, about 20 feet long, has been driven into the upper part of the ash deposit at the southwest end. The ash in the adit is fairly compact but friable. The material is well bedded; the beds dip 17°E and strike N70°W.

This deposit appears to represent a deposit of ash and pumice that accumulated in a pond or lake. Beds of sandstone and tuffaceous sandstone interfinger with the ash beds and the beds may wedge out or thicken considerably in short distances. The entire deposit is capped by a later lava flow.

Although exposures are poor in this vicinity, it appears that chances of developing volcanic ash and pumice are very good.

The volcanic ash from this deposit consists of flattened, angular, broken shards of glass. Clay aggregates and quartz grains make up 5 to 10 percent of the material in the upper ash beds. The glass is fairly fresh; alteration effects are minor.

Figure 43 shows the results of a screen analysis of the volcanic ash from the above locality. The material retained on the larger mesh screens included most of the sand grains contained in the lower volcanic ash bed. Most of the material that passed the 48-mesh screen (0.0116 inch openings) was made up of shards of volcanic glass. In order to produce a suitable pozzolanic material, using ash from this occurrence, screening followed by grinding would be required.

### TABLE 15 - Chemical analysis of volcanic ash, Secs. 31 32, T1S, R21E, Blaine County (A. M. Lothe, Analyst)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>0.9</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>3.8</td>
</tr>
<tr>
<td>SiO₂</td>
<td>69.5</td>
</tr>
<tr>
<td>CaO</td>
<td>1.7</td>
</tr>
<tr>
<td>MgO</td>
<td>0.5</td>
</tr>
<tr>
<td>Total Na₂O</td>
<td>6.2</td>
</tr>
<tr>
<td>Total K₂O</td>
<td>8.5</td>
</tr>
<tr>
<td>Available Na₂O</td>
<td>0.13</td>
</tr>
<tr>
<td>Available K₂O</td>
<td>0.54</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>97.8</td>
</tr>
</tbody>
</table>

A much lower aluminum oxide content is notable in this analysis as compared to analyses of other ash deposits sampled in the state. However, this material should
be chemically suitable as pozzolanic material.

**Pumicite - Lemhi County - T21 and 22N, R20E**

Shockey (1957, p. 13) reports that late Tertiary volcanic ash overlies Tertiary lake beds in the Leesburg basin west of Salmon. He states that the ash is partly indurated and typically brown; it is at least 500 feet thick in the vicinity of Phelan Creek basin. Irregular masses of white ash occur randomly in the brown ash on the north slope of Phelan Creek basin near Leesburg; typical brown ash is overlain by bedded ash and coarse volcanic detritus, according to Shockey.

A brief reconnaissance trip was made into the Leesburg area to see these occurrences, but very little ash was found. Little time was spent prospecting, however, because the region is remote from transportation facilities and market areas, and the occurrences would be of little economic importance.

**Fig. 44** is a map showing the areas reportedly underlain by volcanic ash. This map is taken from Shockey (1957).

Several samples were taken in the vicinity. Most of the material collected can be described as sandy tuff or tuffaceous clay. Shards of volcanic glass are mixed with quartz grains, mica flakes and clay aggregates. Most of the shards in the mixture are highly altered and devitrified.

There are exposures of highly indurated, hard tuff, associated with the Challis volcanics in this vicinity. Such materials have a potential use as building stone.

**Pumicite - Power County - Rockland and vicinity**

The Salt Lake Formation crops out extensively in the vicinity of Rockland in Power County. Volcanic ash members are included in the formation. They can be found at several places along the slopes above Rock Creek and its tributaries (Fig. 45). Many of the volcanic ash deposits are small and insignificant; however, several are large enough to be of interest.

Several deposits were visited and sampled during a reconnaissance of the area; time was not available for complete prospecting of the region, but the deposits discussed below are thought to be representative. Careful examination of the extensive Salt Lake Formation in the Rockland valley would probably reveal many more deposits with a significant tonnage.
Figure 4.4 Map Showing Distribution Of Volcanic Ash, Leesburg Basin, Lemhi County.
SW Corner Sec. 4, T10S, R31E

About 1.2 miles east of Rockland, volcanic ash is exposed as a prominent outcrop on the point of a north-trending ridge (Locality 1, Fig. 45). The ash is fairly compact, but it is friable and is easily excavated from the outcrop. Figure 46 is a close-up view of the ash at this locality.

The ridge drops sharply to the valley of the East Fork of Rock Creek on the south; it has a gentle eastern slope and a steep western slope. The ash is exposed for a horizontal distance of about 200 feet on the western slope of the ridge. The bedding is about horizontal, and the exposure is about 30 feet thick, but the base of the volcanic ash is not exposed. One small pod of sand was noted in the ash.

The ash is gray to white. The glass shards are fine to coarse, and they show little alteration or devitrification.

Sec. 25, T9S, R30E

This locality is about 2 miles north of Rockland near the mouth of a draw called Rocky Hollow (Locality 2, Fig. 45). Volcanic ash occurs along the north bank of this draw for about 400 feet; the ash is about 100 feet thick.

The material is fairly firm, but crumbles easily with hand crushing; it is gray in color. Hillwash gravel covers the slope to the ridge top above the draw. The ash does not form a prominent outcrop, as it does in many other places where ash occurs; the slope of the ridge is rounded and vegetation is abundant.

The ash from this locality is fairly coarse and many of the volcanic glass shards display pumiceous texture. A minor sand content, of from 5 to 10 percent, was noted in the ash.

Secs. 22 and 27, T9S, R30E

From the vicinity of the pumice deposit on the Eliason Ranch (in Sec. 27, T9S, R30E, described in the pumice section of this report), a draw extends north to the valley of Rock Creek (Locality 3, Fig. 45). Volcanic ash outcrops along the sides of the draw for over a mile; the greatest width exposed is about a quarter of a mile, near the mouth of the draw, where a small tributary enters from the east. The difference in elevation from the uppermost to the lowermost exposure exceeds 150 feet.

The dip of the ash beds varies from horizontal to 10° east. The ash is white to gray; a few sand beds are intercalated in the ash. The ash does not form a prominent outcrop in the upper part of the draw, but it forms cliffs 25 feet or more in
height near the mouth of the gully.

Examination of samples from this locality shows that the deposit contains about 15 percent sand. The shards are fresh and clear with little alteration, although they are flattened and the edges of many of the particles are corroded and irregular. They resemble particles of extremely fine pumice. The ash is fairly coarse and abrasive.

Other ash occurrences near Rockland

Volcanic ash is exposed on the east side of Rock Creek for half a mile along a road cut in Sec. 24, T9S, R30E at the west base of a basalt-capped ridge. There is a thickness of about 200 feet of ash between the road cut and the top of the ridge (Locality 4, Fig. 45).

About 6 miles south of Rockland, along State Highway 34, ash, interbedded with sand, occurs along the highway. Most of the ash layers are thin and the ash is contaminated with sand and silt.

Pumicite - Bannock County, Fort Hall Indian Reservation

The reservation was not extensively examined during this investigation. Mansfield (1920, p. 117-118) discusses volcanic ash as a potential economic resource of the reservation. The following is from Mansfield:

In different localities in the reservation, including parts of Tps. 7, 8 and 9S, R32E; Tps. 6, 7, 8 and 9S, R33E; Tps. 4 and 5S; R35E; Tps. 3 and 4S, R36E; and probably other townships, there are extensive deposits of white volcanic ash included in the Tertiary rocks. In some exposures beds 30 to 50 feet thick have been observed. With the kind assistance of H. G. Ferguson, the writer examined under the microscope some of the material of better grade. It contained very little extraneous material and consisted of tiny fragments of volcanic glass and some glassy feldspar. The fragments of volcanic glass contain tiny tubes and vesicles and crystallite. The ash is mostly consolidated into beds that break into easily friable pieces.

Mansfield remarks that the material resembles Nebraska ash that is (in 1920) widely used as abrasive. He presents an analysis of a sample from Portneuf Canyon; it is reproduced below in Table 1.
TABLE 16 - Chemical analysis of volcanic ash, Fort Hall
Indian Reservation, Bannock County, (from Mansfield,
1920)

<table>
<thead>
<tr>
<th>Element</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignition</td>
<td>6.00</td>
</tr>
<tr>
<td>Water</td>
<td>1.60</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>16.22</td>
</tr>
<tr>
<td>SiO₂</td>
<td>68.92</td>
</tr>
<tr>
<td>CaO</td>
<td>1.62</td>
</tr>
<tr>
<td>MgO</td>
<td>trace</td>
</tr>
<tr>
<td>Na₂O</td>
<td>1.56</td>
</tr>
<tr>
<td>K₂O</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>99.92</td>
</tr>
</tbody>
</table>

Pumicite - Bannock County, SW1/4 Sec. 34, T7S, R36E

Ash is exposed in Marsh Creek Valley; and along many of its tributaries in
Bannock County. Much of the drainage is in areas underlain by Salt Lake beds and
small ash outcrops are numerous. The only locality where a significant amount of
ash was seen, however, is in Sec. 34, T7S, R36E. A pit, operated by the Idaho
Portland Cement Co., has been established there. The pit is about 2 miles south
of Inkom on the west side of Marsh Creek. Only a general reconnaissance of Marsh
Creek was made, but undoubtedly large amounts of volcanic ash could be discovered.

The pit in Sec. 34, T7S, R36E is developed in beds of tuff that are fairly
hard and indurated; the tuff breaks into large angular blocks and cleaves into thin
plates. The tuff is bedded, it strikes north and dips 25° east. Figure 47 is a view
of the pit face where volcanic ash has been extracted; it shows the blocky nature
of the material.

Near the base of the exposure a bed of greenish clay occurs; it is creamy
white on a fresh surface. Because the material underlying the clay is not exposed
it is not known if this clay is an interbed or if it marks the base of the tuff exposure.

The deposit is over 200 feet thick as exposed; the outcrop is located on the
sides of a small gully tributary to Marsh Creek from the west. The tuff is resist-
ant to erosion and a prominent knoll marks its occurrence along the top of the ridge
above the draw (Fig. 48).

The tuff occurring at this locality is composed of glass shards and a few
quartz grains. Slight devitrification of some of the volcanic glass fragments has
occurred; they have the general shape and outline of typical glass fragments but demonstrate aggregate polarization. The clay underlying the volcanic ash is composed of silt and volcanic glass that has been altered to clay.

A chemical analysis of the tuff and clay gave the results presented in Table 17:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe_2O_3</td>
<td>0.7</td>
</tr>
<tr>
<td>Al_2O_3</td>
<td>14.4</td>
</tr>
<tr>
<td>SiO_2</td>
<td>59.6</td>
</tr>
<tr>
<td>CaO</td>
<td>1.5</td>
</tr>
<tr>
<td>MgO</td>
<td>1.0</td>
</tr>
<tr>
<td>Total Na_2O</td>
<td>4.7</td>
</tr>
<tr>
<td>Total K_2O</td>
<td>7.2</td>
</tr>
<tr>
<td>Available Na_2O</td>
<td>0.10</td>
</tr>
<tr>
<td>Available K_2O</td>
<td>0.34</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>10.1</td>
</tr>
<tr>
<td></td>
<td>99.2</td>
</tr>
</tbody>
</table>

The pumicite mined at this locality has been used by the Idaho Portland Cement Co. at Inkom in the production of a portland pozzolan cement. Because of little demand for the product, it is now produced only for special orders (G. R. Kingma, November, 1962, oral communication).

**Pumicite - Bear Lake County**

The Salt Lake Formation occurs along the flanks of Bear Lake Valley in Bear Lake County. It is composed mostly of conglomerate but in places there are beds of white marls, calcareous clays, sandstones and grits which furnish a white soil and underlie considerable areas, particularly north of Ovid. A mile or more north of Georgetown, beds of gray volcanic ash dipping 22°E and striking N10°W, are exposed. The exposure is overlain by limestone. The ash outcrop is small; it is about 25 feet long by 10 feet thick. The surrounding area is covered. Little could be learned about the extent of this deposit.
Fig. 46. Photograph of massive volcanic ash outcrop, SW¼ Sec. 4, T10S, R31E, Power County.

Fig. 47. Photograph showing pit face in volcanic ash quarry, Sec. 34, T7S, R36E, Bannock County.

Fig. 48. Photograph of volcanic ash outcrop and quarry, Sec. 34, T7S, R36E, Bannock County. Shows steep cliff developed on volcanic ash.
Extensive outcrops of volcanic ash are found 7 miles north of Emmett in Gem County. The outcrops are located in Secs. 4, 5, 8 and 18, T7N, R1W. Haw Creek is the principal stream in the vicinity of the deposit (Fig. 49).

The beds of volcanic ash are interbedded with clays, silts and fine gravels of the Idaho Formation. Rolling hills, with steep slopes and rounded summits, characterize the topography. Extensive soil and vegetative cover obscure outcrops over much of the area shown in Figure 49, but outcrops can be found in road and stream cuts and near the summits of the higher hills.

Cross-bedding in the sedimentary units can be observed at several localities and attitudes vary considerably in short distances. The general strike is north to northeast and the beds dip 100°-150° west to northwest. The steep topography and the dip of the beds would make extraction difficult and expensive because of excessive overburden.

Beds of ash up to 100 feet thick can be seen at widely scattered localities over the area shown in Figure 49. In the road cut at the top of the ridge separating the Haw Creek drainage on the south from the Bissell Creek drainage on the north, (Locality 1, Fig. 49), ash can be observed on either side of the cut about 150 feet above road level. The ash forms a bed about 36 feet thick on the west side of the road; it is overlain and underlain by fine sand and gravel. The lower 6 feet of the volcanic ash unit contains an appreciable content of diatoms. On the east bank of the road cut the ash is exposed through a thickness of about 15 feet, indicating that the ash may lens out to the east. The volcanic ash crops out intermittently for about half a mile north of the above locality along the bank of a gully east of the road; these beds are 15 to 20 feet thick and they are probably continuous along strike with the beds exposed in the road cut. Farther east, the area is covered by soil and vegetation, but a few very small ash outcrops can be found.

A bed of ash about 40 feet thick is exposed near the head of a wide flat draw that trends southeast in the SW1/4 Sec. 8, T7N, R1W (Locality 2, Fig. 49). The exposure is northwest of the Haw Creek Ranch buildings. The volcanic ash at this locality strikes N25°E and dips 10°W into the hillside; it can be traced for 1,000 to 1,500 feet along the hillside to the west.

Farther south near the head of another wide, southeast-trending draw (Locality 3, Fig. 49), ash is exposed through a thickness of more than 100 feet; it strikes NE and dips NW. Ash can also be seen in several road cuts south of Locality 3 (Fig. 49). The area from Locality 2 to Locality 3 (Fig. 49) might prove to contain a substantial tonnage of mineable ash if detailed exploration were undertaken.
Table 18 is a tabulation of the results of a microscopic analysis of the volcanic ash from Locality 1 (Fig. 49). The samples were taken from the west side of the road cut.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Interval-feet above road level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>+192</td>
<td>Sand and fine gravel</td>
</tr>
<tr>
<td>1</td>
<td>186-192</td>
<td>25-30 percent volcanic glass, shows some alteration and devitrification. Quartz fragments, clay lumps 70-75 percent.</td>
</tr>
<tr>
<td>2</td>
<td>180-186</td>
<td>75-80 percent volcanic glass showing minor alteration to clay; 20-25 percent quartz grains and clay aggregates.</td>
</tr>
<tr>
<td>3</td>
<td>174-180</td>
<td>85 percent fresh volcanic glass, 10-15 percent impurities as silt and sand.</td>
</tr>
<tr>
<td>4</td>
<td>168-174</td>
<td>95 percent fresh volcanic glass, 5 percent impurities as quartz grains, sand and clay aggregates.</td>
</tr>
<tr>
<td>5</td>
<td>162-168</td>
<td>Almost entirely volcanic glass, fairly coarse, pumiceous texture, hard particles, up to 2 inches across.</td>
</tr>
<tr>
<td>6</td>
<td>156-162</td>
<td>Volcanic glass, fresh, clear, fluted structures.</td>
</tr>
<tr>
<td>7</td>
<td>150-156</td>
<td>20 percent volcanic glass, fairly fresh; 30 percent diatom tests, 40 percent clay, 10 percent quartz fragments.</td>
</tr>
<tr>
<td>-</td>
<td>150 to road level</td>
<td>Beds of sand, silt, fine gravel.</td>
</tr>
</tbody>
</table>

The table shows that there are 30 feet of relatively pure volcanic ash between samples one and seven.
Figure 50 is a histogram showing the results of a screen analysis of the volcanic ash from the road cut (Locality 1, Fig. 49). The histogram indicates that light crushing or grinding would be required to produce a product with the fineness required for pozzolanic material.

Table 19 is a chemical analysis of the volcanic ash from the road cut (Locality 1, Fig. 49).

<table>
<thead>
<tr>
<th>Compounds</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>1.2</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>7.7</td>
</tr>
<tr>
<td>SiO₂</td>
<td>61.9</td>
</tr>
<tr>
<td>CaO</td>
<td>1.6</td>
</tr>
<tr>
<td>MgO</td>
<td>0.2</td>
</tr>
<tr>
<td>Total Na₂O</td>
<td>6.2</td>
</tr>
<tr>
<td>Total K₂O</td>
<td>8.5</td>
</tr>
<tr>
<td>Available Na₂O</td>
<td>0.14</td>
</tr>
<tr>
<td>Available K₂O</td>
<td>0.44</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>7.3</td>
</tr>
</tbody>
</table>

The chemical analysis shows that the volcanic ash does not meet the chemical requirements specified by the U. S. Bureau of Reclamation, as the combined SiO₂+Fe₂O₃+Al₂O₃ is less than 75 percent. It is not likely that the material would be a highly suitable pozzolan, but it might find use in some of the other applications mentioned for volcanic ash. Further sampling and analysis might give more favorable results, as the above remarks are based on one sample from a single locality.

The volcanic ash from Localities 2 and 3 (Fig. 49) is fairly pure. Investigation of samples taken show that the ash is slightly contaminated with quartz and clay aggregates in the amount of 10-15 percent; the remainder is fresh, clear, volcanic glass.

Figure 51 represents the results of a screen analysis of the ash from Locality 2 (Fig. 49). The necessity of grinding to produce an extremely fine product is indicated for the material from this locality also.
Table 20 is a chemical analysis of the ash sampled at Localities 2 and 3 (Fig. 49). As in the locality discussed above (Locality 1, Fig. 49), the analysis indicates that the material is too low in silica, iron and alumina to meet the specifications of the U. S. Bureau of Reclamation.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
<td>0.4</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>10.0</td>
</tr>
<tr>
<td>SiO₂</td>
<td>59.8</td>
</tr>
<tr>
<td>CaO</td>
<td>1.3</td>
</tr>
<tr>
<td>MgO</td>
<td>0.6</td>
</tr>
<tr>
<td>Total Na₂O</td>
<td>6.2</td>
</tr>
<tr>
<td>Total K₂O</td>
<td>7.6</td>
</tr>
<tr>
<td>Available Na₂O</td>
<td>0.14</td>
</tr>
<tr>
<td>Available K₂O</td>
<td>0.51</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>9.2</td>
</tr>
<tr>
<td></td>
<td>95.1</td>
</tr>
</tbody>
</table>

According to local residents of the area the Lucky Gem Pozzolan Company was formed in about 1960 in an attempt to exploit this volcanic ash occurrence. Evidently the attempt was unsuccessful as no activity was evident at the time of this investigation in 1963.

OTHER POZZOLANIC MATERIALS IN IDAHO

As noted previously many materials other than volcanic ash can be used as pozzolan. An example of such a material is the calcined opal that is produced as a by-product at the El Paso Natural Gas Co. mercury mine near Weiser in Washington County. The calcined opal is a by-product of the process used for recovering mercury from the ore.

The calcined tailings are highly siliceous; the combined SiO₂, Fe₂O₃ and Al₂O₃ content is approximately 97 percent (M. H. Kline, written communication, December, 1962). In order to evaluate the suitability of the material as pozzolan the El Paso Natural Gas Co. has had extensive testing done by private testing laboratories, producers of concrete products and by the Colorado School of Mines, Golden, Colorado. The tests indicate that the material is a highly suitable pozzolan. No data on the cost of preparing the material for market are available; however, it is indicated that worthwhile savings on cement could be gained through the employment of this calcined opal as pozzolan. Lack of interest in pozzolan by users of cement has hindered the development of this commodity.
Figure 49—Location Map Of Volcanic Ash Occurrence, T7N, R1W, Gem County.

X—Locality 3—Area Discussed In Text
X= Volcanic Ash Outcrop

(Base From Dept. Of Highways County Map Series, With Modifications)
Fig. 50. Histogram showing size distribution of volcanic ash, Sec. 5, T7N, R1W, Gem County.

Fig. 51. Histogram showing size distribution of volcanic ash, Sec. 8, T7N, R1W, Gem County.
VOLCANIC CINDERS

INTRODUCTION

Volcanic cinders are widespread in Idaho and they constitute an important raw material for the construction industry. Cinders are used chiefly as road surfacing, railroad ballast and lightweight aggregate in concrete mixes. Minor uses include aggregate under floors and as loose fill insulation.

Cinder cones are abundant in Idaho, particularly on the Snake River Plain and nearby areas where they are associated with extrusives of the Snake River volcanics. Water-laid accumulations of cinders resulting from erosion of cinder cones can be found at some places in the state.

USES

In Idaho cinders are not widely used as lightweight aggregate. The Idaho Concrete Products Co. of Idaho Falls has attempted to make suitable building blocks with cinders from Shattuck Butte, a large cinder cone west of Idaho Falls. Difficulty was experienced in producing a block with a compressive strength of 1,000 psi. (a grade A block as specified by the A.S.T.M.) and the color of the block was not as desirable as the color of blocks made from pumice (M. A. Ward, written communication, January, 1964). Similar objections to the use of cinders were expressed by Western Block, Inc. of Nampa; the high absorption of cinder aggregate, its abrasiveness and the low compressive strength of the products were found to be undesirable (L. P. Hoffman, written communication, August, 1963). In some states, however, notably Utah, where pumice is not widely available, cinders are extensively used for aggregate. One cinder pit in Caribou County was producing cinders to supply the Utah market in the fall of 1963.

The specifications for cinders as lightweight aggregate are similar to those given earlier in this report for pumice. In some deposits in Idaho alteration and deep weathering have affected the cinders and such cinders are unsuitable. In many instances altered zones of clay and yellowish cinders that must be avoided in mining occur as pods or patches in the main mass.

The use of cinders as road metal and aggregate in highway pavements is becoming increasingly important each year. One reason for the apparent rapid growth of the pumice industry in the United States is because cinder production is included with pumice in the annual figures released by the U. S. Bureau of Mines, Figure 2, a graph showing annual cinder and pumice production over the past several years illustrates this point.
Specifications for cinders as road aggregate are rather broad and not well defined. Abrasion resistance, bulk density and size gradation are important considerations, and these values are usually determined by the Idaho State Highway Department before cinders are used. Crushing and screening are often required to produce the proper sizes. Highly altered cinders are unsuitable because of adverse effects on strength, and the presence of reactive impurities may make a deposit unsuitable.

Cinders are used in road construction only where they are near the point of use and easily extracted. Where extraction costs are high or distance to point of use is excessive, some other aggregate, such as gravel or crushed stone, is used.

Specifications for cinders for railroad ballast mainly concern strength and size of particles; they are not formally defined.

A commercial cinder pit is operated near Nampa by Leland Freiberghaus. The cinders are sold locally as driveway surfacing, fill under floors and as loose fill insulation between wall cavities.

MINING METHODS AND ECONOMIC CONSIDERATIONS

Mining and milling

Cinder deposits are generally well adapted to open-pit mining methods. When cinders are extracted from a volcanic cone a pit is easily developed at the base and mining proceeds upward by a series of benches, or the pit can be extended laterally around the slopes of the cone. When cinders are extracted from a sedimentary deposit or an eroded cone that has little relief, a pit is generally developed downward with a slope at one end of the pit to permit access of equipment and transportation of the product. Overburden is generally of little consequence in cinder production.

Crushing is sometimes required to produce cinders of the proper size. However, cinders from many deposits are used directly as pit-run material. The crushing may be followed by screening, depending on the intended use of the product, but no further processing is generally required.

Economic considerations

The economic considerations for volcanic cinders are similar to those discussed for pumice. In general, the unit value of cinders is less than the unit value of pumice and market areas are more restricted. Pumice is preferred as lightweight concrete aggregate, but cinders have given excellent results as road metal and as highway aggregate. Cinders are used in road construction only where they are near the point of use, however. If relatively long haulage is required, some substitute material can generally be found, such as gravel or crushed stone.
In commercial operations the cinders are generally marketed close to their point of origin. A cinder pit is operated about 10 miles south of Nampa by Leland Freiberghaus and the cinders are sold in the Nampa area. Precise values on the market value of these cinders are not known but they are sold for approximately one dollar per ton, pit-run, and $2.50 per ton, crushed. Cinders from an operation in Caribou County were being sold for concrete aggregate in October of 1963. The pit is located some 8 miles north of Soda Springs, the nearest rail loading point. The market area for these cinders was the Ogden-Salt Lake City area in Utah, some 200 to 250 miles distant. No data are available on the market price for these cinders. The cinders were being shipped by rail as pit-run material. Apparently, under favorable conditions, cinders can withstand relatively long-distance transportation, but in general, like other low-unit-value products, excessive transportation costs tend to make many deposits uneconomic, except for local use.

ORIGIN AND OTHER FEATURES OF VOLCANIC CINDERS

Terminology and origin

Cinders, like pumice, are pyroclastic products formed by explosive volcanic activity, but cinders are associated with basaltic magmas that are less viscous, and the activity leading to the formation of cinders is generally less violent.

Some volcanoes are characterized by rhythmic gaseous emissions that continue for months or even years (Rittman, 1962, p. 12). In this phase of activity the lava is not at a high enough level in the volcanic conduit to be expelled at the surface. If the magma should rise to a higher level in the conduit, fragments and clots of magma are carried upward with the gases and are discharged at the surface. These fragments are cooled during their travel up the conduit of the volcano and during their subsequent flight through the air, and they are deposited as black, slaggery pieces of lustrous, vesicular, glassy cinders or scoria. The fragments often break into finer pieces upon striking the ground. The material ejected in this manner falls around the volcanic vent, forming a steep-sided rampart that results in a volcanic cone. In many instances the cones are elongated in one direction indicating the prevailing wind direction at the time of eruption (Rittman, 1962, p. 76).

If the magma rises to a still higher level in the vent, the ejected fragments have no time to cool down in the conduit or during flight, and they are still hot when they strike the ground. Consequently, the fragments are squashed out flat and may be welded together to form welded scoria. Such material may be deposited over the point of ejection and over fractures in lava tunnels to form low driblet cones, spatter cones or hornitos (Rittman, 1962, p. 77).

Cinders or scoria are about the same size as pumice fragments but they are generally less vesicular and consequently heavier. In the more mobile, basic magmas
gases can escape more easily than from more viscous, silicic magmas. The basic magmas are originally poorer in volatiles so that gases are not as abundant, nor do they release the same pressures exist, as in less mobile, silicic magmas. Therefore, fewer vesicles form in basic pyroclastic material and the activity leading to their formation is less violent.

The quantity of material ejected at any one time from a basic magma, through a volcanic vent, is less than the volume of material ejected from acidic magmas, so there is less abrasion among particles and cinders are typically more jagged and irregular in outline than pumice particles. Vesicles are generally larger in scoria fragments as well (Rittman, 1962, p. 77).

Scoria fragments may acquire definite shapes caused by rotation during flight through the air. Pear shapes and spindle shapes are common; such products are referred to as bombs and several varieties are recognized.

Williams and others (1955, p. 152) define scoria and cinders as names applied to dark, glass-rich, vesicular lapilli and bombs. However, they point out that scoria (but not cinders) may also result from non-explosive activity as froth on the crusts of fluid, gas-rich basaltic flows. When deposits of cinders and scoria are indurated they are called basic tuffs, basic lapilli tuffs or agglomerates, depending on the size of the fragments making up the rock. The nomenclature and size descriptions of particles follow the same classification as for other pyroclastic rocks discussed in the pumice section of this report.

Russell (1901, p. 34, 35) discusses deposits of lapilli in lavas of the Columbia Plateau that developed when a lava flow encountered a body of water. Under such conditions steam is generated, or the water is decomposed, and hydrogen and oxygen are evolved that, if ignited, cause an explosion. At any rate the hot lava is blown into small fragments that are covered by the lava if it continues to advance or by a succeeding lava flow. The fragments are angular, about the size of gravel, and glassy. Cinders or scoria formed in this manner are insignificant as far as large scale cinder operations are concerned as they are usually only local in extent and not accessible to mining.

Bedded, water-laid cinder deposits are found in Ada and Canyon counties associated with the abandoned stream channels of former rivers (Savage, 1958, p. 62). Boulders and cobbles of different types of rocks are intermixed with the cinders and lenses and beds of gravel are found interbedded in the deposits. The commercial pit south of Nampa in Canyon County, is developed on a sedimentary accumulation of cinders. Sedimentary accumulations of cinders are also found in Bonneville County.

According to Williams and others (1955, p. 156, 157) cinders are readily altered, either by surface weathering or from the influence of circulating groundwaters. Devitrification is generally the first result of alteration. If hot deuteritic solutions have been
active, chloritic substances and a greenish material (chlorophaeite) result. The chlorophaeite oxidizes to a yellow and brown material and finally develops a black, resinous luster similar to pitch. Ordinary weathering of basic ejecta generally produces nontronite from the glassy and mafic constituents and calcite, halloysite and kaolinite from the feldspars. Much depends on the acidity or alkalinity of the groundwaters, but the end results of decay are often more or less ferruginous clays (bole and laterite) and bauxite clays.

Most of the cinder cones in the Snake River Plain region have smooth, rounded outlines with slopes of 25° to 40°. Lava domes, composed mainly of bedded lava that erupted from a vent or fissure, form low gentle hills with slopes of 2° to 10°; these are generally distinguishable from cinder cones at some distance. Figures 66, 72, 76, 77 and 78 show examples of cinder cones in the region. Figure 79 shows several spatter cones that are found in Craters of the Moon National Monument.

Physical features and chemical composition

The cinders observed in this study are generally red or black. Under the microscope many of the fine fragments are translucent and resemble fragments of broken, colored glass, especially near their edges. Larger fragments are coarsely vesicular, with thick cell walls. Quartz, calcite and feldspar are often present in the cinders either as secondary material filling vesicles or as discrete crystalline fragments. The bulk specific gravity of volcanic cinders is variable, depending on the number and size of vesicles present and the amount of included crystalline material.

Chemical analyses of red and black cinders show no consistent variation in composition between the two types. The variation in color is probably related to the oxidation state of the contained iron and other alteration effects. The red cinders are preferred for aggregate in concrete blocks, but the preference appears to be related to a more attractive color in the resulting product.

Six cinder samples from the many samples collected throughout the state were chemically analysed. Because of the lack of formal specifications covering the composition of cinders in most applications, the analyses were performed to gain a general idea of the composition of cinders and to investigate the possibility of a correlation between color and composition. The analyses show considerable variation in the composition of the cinder samples. Table 21 shows the range of values and median values for the various compounds determined by the analyses.
TABLE 21 - Chemical composition of volcanic cinders, range of values and median value from samples collected, (A. M. Lothe, Analyst).

<table>
<thead>
<tr>
<th>Compound</th>
<th>Fe₂O₃</th>
<th>Al₂O₃</th>
<th>SiO₂</th>
<th>CaO</th>
<th>MgO</th>
<th>Na₂O</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range %</td>
<td>4.6-9.0</td>
<td>21.0-26.9</td>
<td>42.1-49.6</td>
<td>3.9-9.1</td>
<td>0.2-5.9</td>
<td>5.5-9.3</td>
<td>2.3-8.7</td>
</tr>
<tr>
<td>Median %</td>
<td>8.3</td>
<td>24.5</td>
<td>44.6</td>
<td>6.4</td>
<td>2.0</td>
<td>8.6</td>
<td>5.2</td>
</tr>
</tbody>
</table>

THE VOLCANIC CINDER INDUSTRY IN IDAHO

Volcanic cinder production is closely associated with pumice and pumiceite production. The production and value of all of these commodities are discussed at some length in the pumice section of this report. Figures 2 to 4 depict graphically the trends of production in Idaho and show comparisons to trends in the entire United States. As noted previously much of the growth of the industry in the entire United States is because of increasing production of volcanic cinders. It has also been pointed out that a large part of the cinders produced in Idaho each year are unreported and are not included in the annual production figures. Thus, even though the graphs in Figures 2 to 4 indicate that Idaho production of volcanic construction materials is declining, if all the volcanic cinders produced in Idaho were included, the trend of production would appear more encouraging.

Mining laws applicable to volcanic cinders

The mining laws applying to pumice are applicable to volcanic cinders; the laws are discussed in the pumice section of this report.

VOLCANIC CINDER DEPOSITS IN IDAHO

**Volcanic cinders, Canyon County, Sec. 10, T1N, R2W**

About 10 miles south of Nampa, in Canyon County, red cinders are extracted from a pit for use as a local construction material. The pit is located at the approximate center of Sec. 10, T1N, R2W, about half a mile east of State Highway 45 (Locality 1, Fig. 52). At the time of this visit in May, 1963, the pit was operated by Leland Freiberghaus of Nampa.

The cinders at this locality are water-laid and stratified but they are not consolidated; the cinders are easily removed by a power shovel. According to Savage (1958) the cinders are a part of the Recent Caldwell-Nampa sediments. Savage (p. 27)
Figure 52. Location Map of Volcanic Cinder Occurrences and General Geology, Southern Canyon County.
says that the origin of these sediments is related to floods resulting from a moist climate and consequent overflow into the Snake River valley from pluvial lakes.

The attitude of the cinders is locally variable, but in general they strike about N70W and dip 8° to 15°N. Overburden, consisting of fine silt and soil, varies from one foot to 15 feet around the edges of the pit; the overburden increases northward in the direction of dip. An 80-foot vertical depth was the maximum recorded in the pit at the time of this investigation (May, 1963). Near the top of the pit the beds dip more steeply than near the floor of the pit. Two narrow, interbedded, sandy beds can be seen on an 80-foot vertical face, about 6 feet and 35 feet below the upper edge of the pit. The uppermost sandy beds dips 15°N and the lower 8°N.

The area surrounding the pit is nearly level and most of the ground is under cultivation. Because of the soil cover no further cinder outcrops were observed. However, Leland Freiberghaus, who holds a lease on the cinders, says that drilling indicates that the cinders underlie 17 acres of ground to a depth of 120 feet (personal communication, May, 1963).

The cinders are red, and from 1/4 to 6 inches in diameter. Rounded pebbles and cobbles of crystalline rocks, 2 inches to 6 inches across, are common in the deposit; they are intermixed with the cinders. No attempt is made to sort out the pebbles and cobbles, making up to 5 to 10 percent of the deposit, during mining.

Under the microscope the cinders appear to be highly vesicular, with fairly thin cell walls. A few of the larger fragments have a somewhatropy texture, suggesting that they were derived from the vesiculated surface of a lava flow rather than a cinder cone. Alteration effects are minor, an iridescent bluish coating can be noted on some of the particles.

The cinders are used locally for driveway surfacing, fill under garage floors or other buildings and other local uses. The cinders are marketed as pit-run or crushed to -1/4 inch (L. Freiberghaus, personal communication, May, 1963).

The cinders in the pit are fairly coarse. Figure 57 is a histogram showing the size distribution of the cinders in the pit discussed above. The relatively small percentage of material in the finer sizes, especially below 0.046 inch (14 mesh) demonstrates the coarseness of the material.

The cinders from the pit under consideration were analysed chemically and the results of the analysis are presented in Table 22.
TABLE 22 - Chemical analysis, volcanic cinders, Sec. 10, T1N, R2W, Canyon County, (A. M. Lothe, Analyst)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
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<tr>
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<td>CaO</td>
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<td>MgO</td>
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<td>Na₂O</td>
<td>7.8</td>
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<tr>
<td>K₂O</td>
<td>2.4</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>100.0</td>
</tr>
</tbody>
</table>

Volcanic cinders, Canyon County, Secs. 25 and 36, T3N, R4W

On the north side of the Snake River in Canyon County, cinders are found on the slopes and summit of a northwest-trending ridge. The occurrence is about 2 1/2 miles east of Marsing (in Owyhee County) in the SW1/4 of Sec. 25 and the W1/2 of Sec. 36, T3N, R4W (Locality 2, Fig. 52). Cinder pits are located along a zone about 4,000 feet long in the vicinity (Fig. 53).

The occurrence may represent the site of a fissure eruption of pyroclastic material followed by the extrusion of a minor amount of basalt. According to Savage (1958), the cinders are located in beds of the Idaho Formation of Tertiary age. Outcrops of basaltic lava cap the ridge on which the cinders occur and directly overlie the cinders at some places. Caldwell-Nampa sediments (Recent) occur east of the cinder occurrence.

At the south end of the ridge, near the center of Sec. 36, T3N, R4W, a pit exposes about 50 feet of slightly compacted cinders containing 5 to 10 percent well-rounded pebbles; however, bedding is not evident in the cinders (Pit 1, Fig. 53). These pebbles probably represent material that was torn off the sides of the volcanic vent during the eruption of pyroclastic material through the surrounding Idaho Formation. Four feet of basalt overlie the cinders and caps the top of the ridge.

The capping basalt can be traced around the side of the ridge to the northwest for some 1500 feet. Cinders appear to underlie the basalt throughout this distance. Just south of a road that follows the section line between section 25 and 36, T3N, R4W, a small pit exposes 2 feet of hard, reddish tuff overlying 15 to 20 feet of red, friable cinders. These cinders are bedded; they strike north and dip 15°E (Pit 2, Fig. 53)
Figure 53 Sketch map, Volcanic Cinder Occurrence, Sec.25,36 T2 N, R4 W, Canyon County.
Just north of the section line road a pit 500 feet long by 200 feet wide exposes 50-75 feet of bedded, red, friable cinders that strike north and dip about 10°E (Pit 3, Fig. 53). The pit has been dug into the side of the ridge from road level and is U-shaped in plan. The open part of the U is toward the south. Sand and gravel occur at the surface around the upper edges of the pit; an isolated exposure of basalt occurs slightly west of the pit.

According to Savage (1958), a northwest-trending fault may occur near the east edge of the deposit. Old floodwater channels trending north and northeast appear to have originated near the site of the cinder deposit as well. Just east of the cinder deposit discussed above, and on the east side of the fault, a cinder pit is developed in Sec. 31, T3N, R3W near the township line between R3W, and R4W (Pit 4, Fig. 53). The cinders in this pit are definitely water-laid and contain lenses of sand and gravel. The deposit appears to be localized in Caldwell-Nampa sediments. It is likely that these cinders were derived from the pyroclastics to the east in Secs. 25 and 36, and deposited in their present locality by floodwaters following an old channel. It is also possible that these cinders are on the downdropped side of the fault and that the entire deposit is water-laid.

The cinders exposed in Secs. 25 and 36, T3N, R4W are red, and unconsolidated. Observation with the binocular microscope shows that the material is composed of rusty red, vesicular particles and shards and fragments of translucent glass. Calcite and quartz occur as free grains and as masses filling vesicles. Some of the particles show a dark, resinous, pitchy luster on their surfaces because of alteration, but on a freshly broken surface alteration is slight. Fragments range in size from one inch to fine sand. The cinders from the pit in Sec. 31, T3N, R3W are similar except for 15 to 20 percent included sand and gravel; a 15-foot sand bed is interbedded in the cinders as well.

The cinders in the vicinity are easily accessible to mining and little overburden removal would be necessary. Extensive soil cover on the slopes of the ridge obscure outcrops but it appears that a large volume of cinders exists at this locality. They probably exceed 100 feet in thickness on the ridge.

The cinders extracted have been used for road metal, loose-fill insulation and other local uses. Local residents report that a substantial volume of the cinders extracted at the locality were used for insulation in the construction of cold-storage warehouses. The ownership of the cinders was not determined.

**Volcanic cinders: Canyon County, Secs. 24 and 25, T2N, R3W**

About 3 miles south of Lake Lowell, in Canyon County, a cinder deposit occurs in Secs. 24 and 25, T2N, R3W. The cinders are localized in the Recent Caldwell-Nampa sediments (Locality 3, Fig. 52). Several pits have been dug in the cinders along a zone about 2,000 feet long. The zone extends from the west bank of the
Mora Canal in Sec. 23, northwest to the section line between Sec. 23 and 24 in the SW1/4 of Sec. 24 (Fig. 54). Most of the area is covered and little can be seen except where excavations have been made. There is a possibility that cinders occur over an extensive area, covered by a thin layer of sand and gravel.

Near the west end of a small ridge, at the northwest end of the deposit, 2 feet of hard basic tuff overlie red cinders that contain rounded pebbles of crystalline rocks. The total thickness of these red cinders could not be determined (Locality 1, Fig. 54).

The cinders at the northwestern end of the ridge are rusty red; rounded granitic and quartz pebbles made up about 5 percent of the exposed material. Clay aggregates, detrital quartz, calcite and gypsum are found in many of the fragments as vesicle fillings and intermixed materials; such material may make up 5 to 10 percent of a sample. The weathered surfaces of the cinder fragments are somewhat altered to a resinos, pitchy luster but a fresh surface shows little alteration. The cinder fragments are highly vesicular and glassy. Fragments range in size from 4 inches in diameter to the size of fine sand.

About 600 feet southeast of the ridge mentioned above, there are two large pits that expose 35 feet of cinders, but the total thickness is greater (Locality 2, Fig. 54). The cinders strike N35E and dip 50 to 100N.

The cinders in the two pits are bluish black to black and indurated; the material exposed is more properly basaltic tuff. Individual fragments range in size from 1/2 inch to fine sand. The material breaks into lumps several feet across because of agglomeration of the particles.

Under the microscope the fragments appear to be finely vesicular with numerous vesicles. The weathered surface has a resinous luster; on a freshly broken surface many white, opaque particles of calcite and quartz may be observed and many of the vesicles are filled by a white material consisting of fine needle-like aggregates, probably gypsum.

Approximately 1,000 feet farther southeast, near the west bank of the Mora Canal, in Sec. 25, a small pit exposes black and red cinders (Locality 3, Fig. 54). The black cinders overlie the red cinders; both varieties are well indurated. A thin bed of extremely fine, cemented, dark cinders separates the two types. The black cinders are massive; the contact at the base is horizontal and it truncates the bedded red cinders that dip 130E and strike N20W. In appearance these cinders resemble those already described from other parts of the deposit.

The deposit appears to represent an accumulation of water-laid cinders, but it may be near the site of a fissure eruption. The red cinders would represent the first material ejected and the bedding probably reflects the original slope of a cone.
Figure 54 Sketch map, Volcanic Cinder Occurrence; Sec.24,25 T.2N, R.3W, Canyon County.
Following ejection of the red cinders, gas-charged, viscous material (welded scoria) may have been ejected and is represented by the black indurated tuff now present at the locality.

Although surface exposures are poor, and outcrops of tuff and cinders cannot be traced with assurance from one locality to the next, it seems likely that the deposit is extensive.

**Volcanic cinders, Canyon County, Secs. 10, 11 and 14, T1S, R2W**

Volcanic tuff, associated with Snake River basalt and Recent Caldwell-Nampa sediments, occurs near the south end of Walters Butte in southern Canyon County. The butte is in Secs. 10, 11, and 14, T1S, R2W (Locality 4, Fig. 52).

The massive tuffaceous material at the south end of the butte is bluish-black to black, hard and well indurated. Rounded gravel occurs in the tuff; it is overlain by basalt. At the north end of Walters Butte in Sec. 11, T1S, R2W, red cinders, capped by basalt, are found.

The bluish-black tuff is made up of very fine, highly vesicular, indurated fragments. Most of the vesicles are filled with a foreign material; calcite is particularly abundant. The particles display a resinous luster.

Just south of Walters Butte, on the south side of the Warrens Spur road, in Sec. 23, T1S, R2W, there is a large pit containing loose, fine-grained, bluish-black cinders mixed with gravel and sand. Much of the material in the pit was probably eroded from the tuff on Walters Butte.

No development of the highly indurated tuffaceous material on the butte has been attempted. The loose cinders near the base of the butte have been used locally as road metal. Screening, to remove admixed sand and gravel, could be utilized in the production of a fine-grained lightweight product for use as aggregate or loose-fill insulation, if local markets were present.

**Volcanic cinders, Canyon County, Sec. 24, T2N, R4W**

A small lens of scoriaceous material associated with Recent sands and gravels of the Caldwell-Nampa sediments, occurs in Sec. 24, T2N, R4W in Canyon County. The exposure is about 200 feet long with an exposed height of 20 feet. The deposit pinches out at either end. Basalt overlies the exposure, and it is underlain by fine sand (Locality 5, Fig. 52).
Volcanic cinders, Canyon County, Secs. 4 and 5, T1S, R2W

Dark blue to black, tuffaceous cinders occur in a small pit along the east side of State Highway 45 in Sec. 4, T1S, R2W (Locality 6, Fig. 52). The tuff is capped by Snake River basalt. West of the highway cinders of a similar nature can be seen cropping out along a small west-trending draw. The cinders at this locality are hard, dense and well indurated. They are of limited importance, commercially.

Volcanic cinders, Ada County, Sec. 26, T2S, R4E

Cinder Cone Butte, in Sec. 28, T2S, R4E, in southeastern Ada County, forms a prominent landmark on the surrounding level plain. The butte is reached from the Grandview–Sunnyside road that turns south from Interstate Highway 80N about 16 miles southwest of Mountain Home. A road leads west to Cinder Cone Butte about 9 miles south of the above intersection (Fig. 55). A service road extends to the top of the butte; an electronic installation is located on the summit.

The surrounding country is flat, desert terrain covered by windblown sand and silt that overlies Quaternary Snake River basalt. The butte rises some 300 feet above the relatively flat desert. The base of the butte is roughly circular with a diameter of about 3,000 feet; it slopes symmetrically upward to the summit that displays two flat, rounded peaks separated by a shallow draw. The peaks at the summit are about 200 feet across.

Cinder Cone Butte appears to be composed almost entirely of red and black cinders. At the top of the butte, on its east side, a narrow band of highly scoriaceous basalt crops out. Except for this minor occurrence of basalt, only scoria and lapilli (cinders) were observed. The butte represents a local volcanic vent that ejected a great deal of pyroclastic debris and very little lava.

Cinders have been extracted at several localities from pits near the base of the butte. Most of this material has been used for road metal on state and county roads. The largest pit is located at the south base of the butte (Fig. 55); it is reached from the access road that leads to the top of the butte. Cinders have been extracted from two benches in the pit (Fig. 56). The floor of the upper level is about 25 feet vertically above the floor of the first level. The pit is irregular in outline, the lower bench is approximately 200 feet long, east to west, and 100 feet wide. The walls at the north and east limits of the lower bench are 15 to 25 feet high. The upper bench is about 250 feet long, northeast to southwest, and about 75 feet wide. Along the north side of this bench the face is 20 to 25 feet high. Cinders have been scraped from above this face on a 30 degree slope 75 to 100 feet farther up the slope of the cone.
Figure 55 Location Map of Volcanic Cinder Occurrence, Cinder Cone Butte, Sec.28, T.2S, R.4E, Ada County.
Figure 56 Sketch Map of Cinder Pit, South Base of Cinder Cone Butte, Sec. 28, T2S, R4E, Ada County.
Fig. 57. Histogram showing size distribution of volcanic cinders, Sec. 10, T11N, R2W, Canyon County.

Fig. 58. Histogram showing size distribution of volcanic cinders, Cinder Cone Butte, Sec. 28, T2S, R4E, Ada County.
The cinders in the pit are red to black, and fine to coarse grained. The cinders are rudely bedded, but there is not a great deal of sorting in the various beds. The particles range in size from coarse sand up to 3 inches across; occasionally as large as 6 inches is observed. Individual beds are 1 to 3 feet thick. A very thin layer of fine, agglomerated particles, resembling dark sandstone, separates some of the beds. The dip of the beds conforms to the slope of the butte. At the south base of the butte, in the cinder pit, the beds dip 25° south to southeast; they strike west to northwest.

There is another pit at the north base of the butte, it is somewhat smaller than the pit just described. The cinders from both localities are similar.

The volume of material in Cinder Cone Butte is not known. According to the State Highway Department there are approximately 1,000,000 tons of cinders at this site (R. G. Charbonneau, written communication, August, 1963).

Cinder samples were taken at several localities on the slopes of the butte. The materials collected were examined microscopically and subjected to laboratory tests. Microscopic observations indicate that the cinders are highly vesicular with fairly thick cell walls. Many of the vesicles are filled with calcite or silica. The dark cinders resemble minute pieces of highly scoriaceous lava. When the dark fragments are finely crushed, a small amount of fine, clay-like aggregates can be seen. A black iridescent sheen is developed on the surface of some of the dark fragments. The red cinders are made up of a large number of translucent, glassy, shard-like particles that are yellowish brown. Some of the fragments have a fibrous structure that, when finely crushed, consists of an aggregate of curved, fluted, glassy fragments. The difference in the two types of cinders probably represent differences in mode of origin and subsequent alteration.

Most of the cinders in the deposit are fairly fine, resembling very coarse sand or very fine pebbles in size. A histogram showing the size distribution of a screened sample is presented in Fig. 58. The histogram demonstrates that over 50 percent of the sample is in the size range of 0.371 inches to 0.046 inches (14 mesh).

Two samples from Cinder Cone Butte were analysed chemically. One sample represents red cinders, the others represent black cinders. Both analyses are presented below (Table 23). The analysis of the red cinders is the most representative as red cinders are much more abundant.
TABLE 23, Chemical analyses of volcanic cinders, Cinder Cone Butte, Sec. 28, T2S, R4E, Ada County, (A. M. Lothe, Analyst)

<table>
<thead>
<tr>
<th></th>
<th>Red cinders</th>
<th>Black cinders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe$_2$O$_3$</td>
<td>8.3</td>
<td>8.2</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
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<td>SiO$_2$</td>
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<td><strong>100.0</strong></td>
<td><strong>98.4</strong></td>
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</tr>
</tbody>
</table>

**Other cinder deposits, southwestern Idaho**

According to R. G. Charbonneau, District Geologist, Idaho Department of Highways, District 3 (written communication, August, 1963) the utilization of volcanic cinders for aggregate in road construction and maintenance in the southwestern part of the state, by the Department of Highways, is minor because of an abundance of sand and gravel. Sources of volcanic cinders mentioned by Charbonneau were Cinder Cone Butte (discussed above); Sec. 16, T3S, R6E, Elmore County; and Sec. 20, T4N, R8E, Elmore County. Neither of the localities in Elmore County was visited during this investigation.

The source in Sec. 16, T3S, R6E is described as black to red scoriaceous cinders of the Snake River basalt group with a potential of 1,500,000 tons. The cinders weigh 48 to 50 pounds per cubic foot.

The source in Sec. 20, T4N, R8E has an estimated potential in excess of 1,000,000 tons. The material is described as black to red scoriaceous cinders.

**Volcanic cinders, South-Central Idaho**

In South-Central Idaho (District 2 of the State Highway Department) there have been only two projects involving volcanic cinders since 1958; two cinder deposits will be utilized within the next three years (F. A. Oneida, written communication, April, 1964). The deposits described below in Gooding, Jerome, Lincoln and Minidoka counties were not visited during this investigation; the following descriptions are taken from information submitted by F. A. Oneida, District Geologist, District 2, Idaho Department of Highways (written communication, April, 1964).
Gooding County, Sec. 11, T6S, R14E

This deposit is located on the Gooding airport road. It is described as a scoria formation with dense layers intermixed. There has not been any production from the deposit.

Jerome County, Sec. 4, T10S, R19E

This deposit is located on Eden Butte in Jerome County about 2 miles south of the village of Eden. It is described as a scoria formation with dense layers intermixed. The material breaks up into large blocks when excavated. The cinders are designated for use on three interstate highway projects.

Lincoln County, Sec. 2, T7S, R21E

A pit at this locality, about 15 miles east of Dietrich, Idaho, has produced 37,970 tons of crushed cinders and scoriaceous basalt. The material is generally scoriaceous basalt with some cinders and layers of denser basalt intermixed. The material produced was crushed before use.

Minidoka County, Sec. 31, T9S, R22E

This source, about 7 miles west of Paul, in Minidoka County, is generally a cinder deposit with a thick layer of scoriaceous lava interbedded in the cinders. Much of the material in the deposit underlies a triangulation point and no equipment can be used within 75 feet of the brass cap. Some 43,000 tons of cinders and scoria from this deposit have been removed and crushed.

Lava fields south of Arco, Butte County

The recent lava fields south of Arco and southeast of Craters of the Moon National Monument in Butte County were investigated for occurrences of cinders. Small rounded hills and domes are abundant in the area but these are composed principally of vesicular lava. The lava is red and highly scoriaceous near the tops of many of the domes, and the material would be suitable for highway aggregate, but the amount available is limited because hard, fresh, dense lava underlies the scoriaceous material. A large, black cinder cone, Black Butte, reportedly occurs outside the limits of Craters of the Moon National Monument about 5 miles southeast of Vermillion Chasm (Stearns and others, 1938, p. 94). An attempt to locate this cone was not successful.
Volcanic cinders, Clark and Fremont counties

There are many volcanic buttes in Clark and Fremont counties. Some of these buttes are cinder cones; others are lava cones, tuff cones and spatter cones. According to Stearns and others (1939, p. 32), some of the more notable cinder cones of the region are: Egg Butte, Red Top Butte, Jones Butte, Snowshoe Butte, Crystal Butte, Fogg Butte, Swan Butte, High Point Butte and others (Fig. 59). Many of the localities are remote and difficult of access but large quantities of cinders are represented and may at some time be of importance. Because of the large number of cinder cones in the region it was not possible to visit them all. Swan Butte was visited as was High Point. At many of the buttes heavy soil and vegetative cover make evaluation of the occurrence and collection of samples difficult.

Swan Butte, Sec. 1, T11N, R38E

Swan Butte is located in Clark County about 3.5 miles south of Idmon, near the road leading to St. Anthony, in Fremont County, (Fig. 59). The cone is elongate to the northwest; at the base it is about half a mile long and a quarter of a mile wide. The butte stands some 300 feet above the adjacent plain. A pit on the north slope exposes 150 to 200 feet of cinders, otherwise grass and soil cover the slopes of the cone.

The cinders exposed in the pit are fairly fine, ranging in size from coarse material, about 3 inches across, to fine material approximating the size of coarse sand. Large fragments up to a foot or more in diameter are included in the finer material, but they are not numerous. The cinders are black to red and rudely bedded; the attitudes of the beds parallel the slopes of the cone; dips range from 10 to 20 degrees. Several soil zones a quarter of an inch or so thick can be seen between the beds of cinders.

Large bombs and blocks of pyroclastic ejecta mantle the surface of the cone; small crystals of clear feldspar, up to an inch long, occur with many of the bombs. Some of the crystals fill vesicles and others occur as discrete particles in the mass of scoriaceous ejecta; many small crystals also mantle the surface. According to Stearns and others (1939, p. 32) Crystal Butte in Sec. 11, T11N, R40E, farther east, is similar, in that many feldspar crystals can be found on the surface of the cone.

There is a large depression at the summit of Swan Butte which is evidently the crater from which the material making up the cone was ejected. Hard vesicular lava encircles the crater rim, but the bulk of the material making up the cone is cinders.

So far as is known, the cinders extracted from the pit have been used locally as road surfacing aggregate.
Figure 59 Location Map Of Cinder Cones, Clarn And Fremont Counties With General Geology.
High Point Butte, Sec. 19, T11N, R42E

High Point Butte is a cinder cone located in Fremont County about 15 miles north of Ashton and 4 1/2 miles west of U. S. Highway 20 and 191 (Fig. 59).

The cone rises several hundred feet above the adjacent plain and is heavily timbered. The symmetrical slopes are mantled by a thick soil and brush cover; there are few outcrops. At the summit a few loose cinders can be seen on the surface but in general, exposures are too poor to permit proper evaluation of the occurrence. It appears that the entire butte is made up of cinders but little could be learned of the size gradation or quality of the material. The cone is about 0.6 mile, north to south, and 0.4 mile, east to west, at its base. A rough, unmaintained road leads to the top of the cone.

Volcanic cinders, Jefferson County

Several sources of cinders have been tested in the vicinity of Mud Lake and Menan Craters in Jefferson County by the Idaho Department of Highways. The information presented below is taken from data submitted by T. R. Markland, District Geologist, District 6, Idaho Department of Highways (written communication, January, 1964). These deposits were not visited by the writer.

Volcanic cinders, Sec. 21, T7N, R35E

This volcanic cinder occurrence is found in the vicinity of Mud Lake about 4 miles east and 6 miles north of Terreton, north of State Highway 28, (Locality 1, Fig. 60). An estimated 900,000 cubic yards of cinders occur at the locality. The estimate is based on the results of several test holes put down on the deposit. One of the holes encountered basalt underlying the cinders at the edge of the occurrence.

Little was learned by the writer about the type of deposit represented at this locality. Late basalts of the Snake River volcanics are the predominant rock type in the vicinity. The Mud Lake Craters are less than a mile to the north; these craters are depressions in lava cones and driblet cones (Stearns and others, 1939, p. 31). It is likely that the origin of the cinders found in the area is related to the origin of these volcanic cones.

The cinders have a dry weight of 85 pounds per cubic foot. The results of a screen analysis, showing the size distribution of the material, are shown in Fig. 62.
Volcanic cinders. Sec. 17, T7N, R3SE

The cinders at this locality (Locality 2, Fig. 60) are near the south edge of the Mud Lake Craters in the same general area as the cinders at Locality 1 (Fig. 60). The material is described as black volcanic cinders with some vesicular basalt. No estimate of the volume was given except that there is an ample quantity of material. The size distribution of these cinders is very similar to that at Locality 1 (Fig. 60). The cinders weigh 101 pounds per cubic foot.

Volcanic cinders. Sec. 20, T7N, R3SE

This locality (Locality 3, Fig. 60) is in the same general area as the deposits at Localities 1 and 2 (Fig. 60), and the material is similar; it is described as black cinders with some vesicular basalt. The cinders weigh 97 pounds per cubic foot. The size distribution of the particles follows closely the size distribution shown by the histogram in Fig. 62.

Volcanic cinders. Sec. 29, T6N, R3E

This locality (Locality 4, Fig. 60) is about a mile north of Menan Buttes in eastern Jefferson County on the flanks of a small tuff cone. Stearns and others (1939, p. 32) say that this locality is one of the few places on the Snake River Plain where evidence of violent, explosive volcanic activity can be found associated with the Quaternary Snake River lavas. According to Stearns and others (p. 33):

A large part of the material composing the cones is basic ash, in part pisolitic. The curved shards that make up much of this ash show clearly that it was derived from walls of vesicles of the glassy froth of an expanding, gas-charged, basaltic magma.

The ash is bedded and dips away from the summits of the cones at angles of 20°-30°; it becomes nearly horizontal near the edges. The beds dip inward from the rims of the crater found at the summits of the cones. The tuff is partly indurated, but fine basaltic sand, derived from erosion of the cones, surrounds their bases. Basaltic blocks derived from earlier flows, quartzites and fragments of other sedimentary rocks are found associated with the tuff. The tuff is consolidated but fairly soft and easily removed. At Road Butte, another tuff cone located about 2 miles south of Menan Buttes, much of the material ejected was river gravel, and much of it is unconsolidated (Stearns and others, 1939, p. 33).

The cones are aligned along a northwest-trending zone 7 miles in extent that includes five volcanic vents. Stearns and others (1939, p. 34, 35) think that spasmodic eruptions took place more or less simultaneously from the vents and that the explosions were not very powerful. Collapse of the confining walls of the fissures fed in supplies of gravel and sand. Stearns and others (p. 35) also postulate that the
Figure 60 Location Map Of Volcanic Cinder Deposits, Jefferson County, Showing Generalized Geology in Vicinity.
Figure 6: Map and Cross section, Volcanic Cinder Occurrence, Secs. 29 and 32, T6N, R38E, Jefferson County
Fig. 62. Histogram showing size distribution of volcanic cinders, Sec. 21, T7N, R3SE, Jefferson County.

Fig. 63. Histogram showing size distribution of volcanic cinders, Secs. 29 and 32, T6N, R3E, Jefferson County.
energy for the eruptions was derived from heated ground water that caused steam explosions.

Drill holes and trenches at the locality tested by the Idaho Department of Highways indicate a volume of 500,000 cubic yards of cinders suitable for road aggregate. The shape of the deposit is shown in Figure 61. Some of the cinders near the top of the cone are very firmly consolidated and difficult to penetrate, but in general, the material is loose and easily extracted. None of the holes drilled reached depths greater than 50 feet, and except for a few feet of soil near the tops of some of the holes, cinders were the only material encountered. Screen analyses of samples obtained from trenching with a backhoe indicate that the size distribution of the material in the cone is fairly evenly distributed between 3 inches and 200 mesh (0.0029 inches), (Fig. 63). The cinders weigh 88 pounds per cubic foot.

**Volcanic cinders, Bonneville County, Sec. 19, T2N, R43E**

Cinders are found in Bonneville County on the ridge at the north side of Conant Valley about 6 miles northwest of Swan Valley (Fig. 4). A pit, high on the south slope of the ridge, is easily visible when northbound on U. S. Highway 26. The pit cuts through the crest of the ridge.

A succession of cinders, about 150 feet thick, well enough compacted to be called a tuff, has been mined at this locality. The material is hard and well indurated; many angular pieces of basalt are included in the deposit, as well as a minor number of rounded quartzite pebbles. Large vesicular fragments 2 to 3 inches across occur in a matrix of darker colored fines; many of the larger fragments are altered to a tan or orange color; on a broken surface, these fragments are an iridescent blue. The cinders are stratified as if water-laid. Savage (1961b, p. 57) states that these pyroclastics probably accumulated in a ponded environment, because of pillow lavas associated with the cinders, and the suggestion of an old shore line, that is indicated by the presence of cobbly gravel layers above the pillow lavas. The beds dip about 10 degrees south. From the pit the cinders are exposed to the north for a quarter of a mile or more along Highway 26.

The cinders are capped by basalt, and basalt overlies similar tuff west of the pit along the steep north wall of Conant Valley. South of the pit, and downslope, fine red to black volcanic sand and soil cap the ridge; the sand contains fragments of coarser pyroclastics as well as rounded quartzite pebbles. The sand and included material is fairly well indurated; it appears to overlie basalt that caps tuff similar to that exposed in the pit. Several test pits have been dug on the ridge crest but they are too shallow to expose the underlying material. Overburden ranges from 2 to 14 feet (T. R. Markland, written communication, January, 1964).

According to Savage (1961, p. 57), the cinders extracted from this pit have been used for road ballast. It is doubtful if the material would be suitable as lightweight
concrete aggregate because many of the fragments are highly altered; in addition there is a considerable amount of silt admixed with the cinders, and mining would be somewhat compromised by the compact nature of the material. The State Highway Department has tested this occurrence with a series of drill holes as a source of highway aggregate. They concluded that there are 700,000 cubic yards of acceptable material in the deposit (T. R. Markland, written communication, January, 1964).

Volcanic cinders, Bonneville County, Shattuck Butte
Secs. 7 and 8, T3N, R37E

A large cinder cone, Shattuck Butte, is found in Bonneville County about 8 miles north and 5 miles west of Idaho Falls (Fig. 66). Cinders have been extracted from three localities on the flanks of the cone. A crater, breached by erosion, is located near the center of the cone; a large draw leads northwest out of the crater. The summit of the cone is at an elevation of about 5,150 feet some 200 feet above the adjacent plain. The floor of the crater is at an elevation of about 5,050 feet, (Fig. 65).

A large pit is situated on the northeast side of the cone in Sec. 8 near the southwest corner of the NW1/4 of the section. The cinders are black and massive; bedding is not pronounced (Fig. 67). Small patches or zones of silt and altered cinders occur in the walls of the pit surrounded by black, massive, unaltered cinders. One such occurrence can be seen on the east wall of the pit where light-colored altered, bedded cinders, dipping 35° to 45°N, away from the slope, finger out into black, massive cinders on the east and west. The exposure is about 25 feet long by 15 feet high. The conditions leading to the development of this zone are not known, but it was probably caused by a local ponded condition at the time of eruption.

The cinders in the pit in the NW1/4 of Sec. 8, are fairly fine; most of the individual particles are between a quarter and half an inch across. The material is only slightly compacted. Several small fractures, dipping steeply at various angles, cut the deposit. Blocks of scoriaceous, angular basalt are included in the cinders, but they are not numerous. On the west side of the pit 50 to 75 feet of cinders are exposed; the floor of the pit is also made up of cinders.

Soil and overburden are exposed south of the pit. On the west, across a shallow depression, are the soil-covered slopes of the main cone. The pit is rimmed by highly scoriaceous basalt on the north and east; the basalt occurs in thin sheets, dipping northeast, away from the slope of the cone. The configuration of the topography and the presence of the outward-dipping flows suggest that this pit is in a secondary crater that gave rise to a small lava flow.

A second pit is located in Sec. 7 about a quarter of a mile north of the southeast corner of the section, near the east section line. This pit is on the southeast slope of the cone at an elevation of about 5,050 feet. The cinders at this locality are red to dull, dark maroon. The pit exposes coarse fragments, 2 to 3 inches across, in a matrix of
Figure 64  Location Map Of Volcanic Cinder Occurrence, Conant Valley, Sec.19, T2N, R43E, Bonneville County.
Figure 65 Location Map, Volcanic Cinder Deposit, Shattuck Butte, Secs 7, 8, T3N, R37E, Bonneville County.
Fig. 66. View of Shattuck Butte, Secs. 7 and 8, T3N, R37E, Bonneville County. Looking west from one half mile east of butte.

Fig. 67. View of cinder pit showing massive cinders on northeast side of Shattuck Butte, Sec. 8, T3N, R37E Bonneville County.

Fig. 68. View of cinder pit showing coarse fragments in matrix of fine cinders. Shattuck Butte, Sec. 7, T3N, R37E, Bonneville County.

Fig. 69. View of a portion of a cinder pit showing scoria intermixed with cinders, Shattuck Butte, Sec. 7, T3N, R37E.
fine, sand-size cinders (Fig. 68). The histogram in Figure 74 shows the size distribution of the material in the pit. The cinders weigh 98.0 pounds per cubic foot (T. A. Markland, written communication, January, 1964). Numerous angular pieces of scoriaceous basalt, 1 inch to 6 inches across, are included in the material. Several small fractures cross the pit; in the vicinity of the fractures the cinders are altered to a yellowish tan color. Fine white soil, 2 to 3 feet thick, overlies the material at the rim of the pit. The pit enters the hillside from the south and turns east at about a right angle to the slope. About 100 feet of cinders are exposed on the upper side of the pit with cinders in the floor. The pit is 400 to 500 feet long and about 100 feet wide.

A third pit is located on the south slope of the cone near the northeast corner of the SW1/4 SE1/4 Sec. 7, T3N, R37E, at an elevation of 5,030 feet. The cinders at this locality are similar in appearance to those in Sec. 7, described above, except for an abundance of intermixed large fragments of red,ropy, scoriaceous material (Fig. 69).

The cinders dip outward, away from the hillside at 25 to 35 degrees. The pit is about 300 feet long by approximately 100 feet wide; 50-75 feet of cinders are exposed in the walls of the pit. A basalt flow occurs just south of the pit; it was probably extruded from the main vent near the close of the eruptive cycle; the main crater is about 500 feet north of the pit and separated from it by a small ridge. If the overburden was removed north of the pit, the flow would probably be exposed there as well.

The ownership of these cinders is not definitely known. Savage (1961b, Fig. 20, facing p. 38) describes an illustration of a cinder pit on Shattuck Butte as being state-owned. The material has been used as highway aggregate. One of the pits is owned by the Idaho Concrete Products Co. of Idaho Falls and the material has been used at times as aggregate to make building blocks. However, in their experience, pumice is more suitable for block manufacture, as the cinders from this locality are too soft and it is difficult to produce a block with a compressive strength of 1,000 p.s.i. gross area. In addition, their pumice blocks have a fire-rating approval, and are of a more pleasing color (M. A. Ward, written communication, January, 1964). The Bonneville County Road Department has used a considerable quantity of the cinders from Shattuck Butte on roads in the area (M. A. Ward, written communication, January, 1964).

A large quantity of cinders has been extracted from Shattuck Butte and a large volume is still available. They appear to be of good quality, however, it was noted while sampling the material that the larger fragments are brittle and tend to break readily. This condition could cause the cinders to be deficient in coarse material and to be unsuitable for lightweight concrete aggregate, as indicated by the experience of Idaho Concrete Products.
Volcanic cinders, Bonneville County, Sec. 13, T3S, R42E

Cinders occur on the flanks of an eroded volcanic cone at this locality in southwestern Bonneville County (Fig. 70). The cinders are associated with indurated basaltic tuff and scoriaceous lava.

The cone stands 150-200 feet above Outlet Valley, about 2 miles north of the north end of Grays Lake, near the small settlement of Herman. The cone has been eroded and now has the form of a ridge trending northeast; it turns sharply west at its northeastern end. The ridge is about a quarter of a mile long by a thousand feet wide. A gully has cut through the cone on its southeast side and a ridge capped by highly scoriaceous, ropy lava has been isolated from the main cone by this gully. The basalt layers dip east. Tuff occurs at the north end of the ridge. The tuff is red and it dips steeply north. The west slope of the ridge is covered; it is not steep, but slopes gently down to the cultivated valley floor. A pit is located on the south slope of the cone near the summit. On the south the cone slopes gently upward from a basalt flow exposed in the valley. Loose pieces of scoria are abundant on the soil-covered summit of the ridge.

The material in the pit is composed of lapilli and scoria; the fragments range in size from 1 inch to 12 inches across. The cinders are massive, and bedding is not evident. There are approximately 30 feet of cinders exposed in the pit. South of the pit the terrain is covered but chances of exposing more cinders by a few shallow exploration pits are good, and a large volume of material could be made available. About three-quarters of a mile north of this locality a small rounded hill can be seen; its slopes are completely soil covered, but loose pyroclastic debris in the vicinity indicates that this hill is probably a cinder cone also.

There is a good road leading west from Herman which is surfaced with cinders from this locality.

Volcanic cinders, Bonneville County, NW1/4 Sec. 21, T3S, R42E

A pit has been developed on the slope of an eroded cinder cone near the west side of Outlet Valley; cinders have been extracted from the pit for use as road ballast (Fig. 70). The cone is roughly circular in plan; it is eroded and dissected on the west; the east front is quite steep. There are no exposures on the cone except for a pit developed on the east flank about midway up the slope. The cone is about 750 feet in diameter at the base; it stands about 150 feet above the adjacent valley.

The deposit consists of red, unsorted fragments ranging in size from 1 inch to 15 inches across. Although exposures are too poor to be certain, it is likely that the entire cone is made up of cinders.
Figure 70  Location Map, Volcanic Cinder Deposits, Sec.13 & 21, T3S,R43E, Bonneville County
There are several other hills and domes in the vicinity that appear to be cinder cones. Because of time limitations it was not possible to visit them all, however, it can be said that cinders are a widespread and abundant commodity in this locality. Many of the roads in the area are surfaced with cinders.

Volcanic cinders, Bonneville County, Sec. 26, T4S, R42E

A pit is located about 1.7 miles north of State Highway 34 along the road that follows the west shore of Grays Lake; the pit is about a half mile west of the lake. This excavation was evidently a source of cinders used locally for road surfacing. The pit cuts through what appears to be a small tuff cone.

Basalt is exposed on the floor of the pit indicating that the bottom of the deposit has been reached. Massive scoria and ash, exposed on the sides of the cut, make up the material remaining in the deposit.

Volcanic cinders, Bonneville County, Sec. 11, T2N, R36E

This locality, known locally as Cinder Hill, is in the S1/2 of Sec. 11, T2N, R36E, about 7 miles west of Idaho Falls along U. S. Highway 20. It was not visited during the present investigation. Information concerning the deposit was learned from the Idaho Department of Highways, District 6, (T. R. Markland, written communication, January, 1964).

There are an estimated 100,000 cubic yards of volcanic cinders in the deposit that have a dry weight of 98.0 pounds per cubic foot. The deposit appears to be associated with a cinder cone.

Volcanic cinders, Bonneville County, T3N, R40E

According to Savage (1961b, p. 58), there is a large volume of water-laid pyroclastic material on the north side of the Snake River near Table Rock, 5 to 6 miles west of Poplar in Bonneville County. Savage goes on to say that gray to brown ash, silt and fragments of scoria and obsidian are exposed, and the material is highly indurated which limits the commercial value of the deposit. This occurrence was not visited during the present investigation.

Volcanic cinders, Blackfoot Lava Field, Caribou County

The Blackfoot Lava Field is an extensive area underlain by basalt occurring north and west of Soda Springs. Over much of the region soil cover of sufficient depth to support vegetation overlies the basalt, and extensive agricultural development has taken place.
One of the most striking features of the basaltic plain is the number of volcanic cones rising above the lava field. Many of the cones are made up of cinders, and this commodity is abundant in the area. Cinder pits have been excavated at many localities in the region because cinders are widely used as road surfacing material.

Not all of the possible sources of cinders in the vicinity were visited during this investigation. Many of the cones are soil and grass covered so that little can be learned about the character of the material (Fig. 72). However, there is little variation in the pyroclastics from one locality to another, so a general idea of the characteristics of the cinders in the region was gained from those localities that were investigated. In addition to the cinder cones, three large rhyolitic cones stand at the south end of Blackfoot Reservoir. These rhyolitic cones are surrounded by the basaltic lavas of the lava field (Fig. 71).

Figure 71 is a map showing a portion of the lava field and the location of some of the more important lava cones in the area. This map was compiled from maps presented by Mansfield (1927).

In addition to the cinder cones occurring on the lava plain, two large lava cones, each surmounted by one or more cinder cones with craters, occur in the area. These are Crater Mountain in Sec. 14, T5S, R41E, Caribou County, and Sheep Mountain, in Bingham County; it occupies parts of Secs. 4, 5, 6 and 10 in T3S, R41E. Neither of these features was visited.

Sec. 26, T7S, R41E

Cinders are mined commercially from a pit in Sec. 7, T7S, R41E, about 10 miles north of Soda Springs (Locality 1, Fig. 71). The cinders are shipped to Ogden, and Salt Lake, Utah markets for use as lightweight aggregate in building block production.

The cinders are extracted from the flanks of a volcanic cone. The material is red; however, bands of yellowish, altered cinders occur in the deposit, particularly in the upper part. When viewed with a microscope the red cinders appear fresh and highly vesicular; small crystalline inclusions of feldspar can also be observed. The yellow, altered cinders break down in water to a soft, clay-like mass; in polarized light they show aggregate polarization similar to clay. These yellow zones appear to represent local patches of clay alteration in the deposit. Altered cinders are avoided in mining as they are not suitable as aggregate. The cinders are coarse and there is a minimum of fines, as demonstrated by the histogram of the size distribution shown in Figure 75. The bulk density of the cinders is about 71 pounds per cubic foot. A very large pit is developed at this locality (Fig. 73).

A chemical analysis of the red cinders gave the results shown in Table 24.
TABLE 24 - Chemical composition of volcanic cinders, Sec. 26, T7S, R41E, Caribou County, (A. M. Lothe, Analyst)

<table>
<thead>
<tr>
<th>Compound</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe₂O₃</td>
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</tr>
<tr>
<td>Al₂O₃</td>
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<td>SiO₂</td>
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<td>CaO</td>
<td>8.3</td>
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<tr>
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<tr>
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</tr>
<tr>
<td>K₂O</td>
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</tr>
<tr>
<td>Loss on Ignition</td>
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</tr>
<tr>
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<td>99.7</td>
</tr>
</tbody>
</table>

The cinders are rudely bedded; near the top of the deposit the bedding is about horizontal; at the base, near the bottom of the pit, the material dips more steeply. At most of the cones visited, the opposite relation is true, that is, the dip increases upward. This reverse situation could be explained by the occurrence of two periods of eruptive activity in which the lower material represents the product of an earlier cinder cone. If a period of erosion occurred, after the development of the earlier cone, and a second eruption of material took place later, but involved a much smaller volume of ejecta, the material from this second eruption would overlie the older pyroclastics with a nearly horizontal attitude. Not enough is known about the eruptive cycles of the region to definitely establish this circumstance, however.

According to S. Hawker (personal communication, October, 1963), of R. B. Hawker and Sons, the firm mining the cinders, 400 to 500 tons of cinders are mined per day at a cost of about $0.10 per ton. Hawker also remarked that concrete block with a compressive strength of 600 p.s.i. is produced with the cinders. The pit is owned by R. Hubbard, of Alexander. The cinders are trucked from the pit to Soda Springs and shipped by rail to Utah markets.

Another cone, probably composed of cinders as well, is located several miles east of this pit (Locality 2, Fig. 71).

Secs. 8, 9, 10 and 17, T7S, R41E

Broken Crater is a large cinder cone located in Secs. 9 and 10, T7S, R41E (Locality 3, Fig. 71 and Fig. 76). It is breached on its south side where a large draw leads out of the crater. According to Mansfield (1927, p. 121) the crater was probably breached by an explosion. The breach has been enlarged by erosion since, however. Another cinder cone is located about a mile west of Broken Crater in
Secs. 8 and 17, T7S, R41E (Locality 4, Fig. 71). The summit of this cone is about 100 feet lower than the summit of Broken Crater. Broken Crater stands about 600 feet above the surrounding lava field. A lava flow extends northward from the area between the two cones. The base of Broken Crater is surrounded by wheat fields on the east and north; lava is exposed to the south.

The slopes of the cones are covered; at the top of Broken Crater reddish bombs, scoria and lapilli are evident as loose debris mantling the surface. There are also several isolated outcrops of tuff composed of red scoria and other pyroclastic debris at the summit; the material is indurated but it breaks readily.

A large volume of cinders occurs at Broken Crater and the neighboring cone. Broken Crater is about three-quarters of a mile in diameter at its base and the cone to the west is about a half mile in diameter at its base. The area occupied by these cones when considered in conjunction with their elevations, is indicative of the volume of material present. Much of the surrounding country is soil covered and under cultivation; Mansfield (1927, p. 121) remarks that the two cones are surrounded by basalt except for a low point, on the northeast side of Broken Crater where red scoria, similar to the material making up the cones, extends for 300 feet from the base of Broken Crater.

Sec. 34, T6S, R41E

Little Crater is located near the boundary between T6S and T7S, R41E, near the southeast corner of Sec. 34 in T6S (Locality 5, Fig. 71). Little Crater is the most symmetrical cone seen during this investigation. It is almost circular in outline. Mansfield (1927, p. 36) remarks that Little Crater is the finest example of a cinder cone in the region and that its shallow crater forms nearly a perfect circle (Fig. 78). The top of the cone stands some 200 feet above the surrounding plain. The base is about 1,200 feet in diameter; the crater at the summit is about 200 feet across and 20 feet deep.

Black scoria mantles the top of the cone. A small, hand-dug pit near the west rim of the crater shows highly vesicular, red to black cinders. The surface of the cone is covered by soil and vegetation. The pit mentioned above is the only exposure of the material of which the cone is composed.

NW1/4 Sec. 14, T6S, R41E

At a locality about 5 miles north of Soda Springs, cinders have been extracted from the flank of a cone (Locality 6, Fig. 71). At the top of the cone a shallow crater can be seen that has been breached by a north-trending draw. Lava flows, probably extruded from the cone, lie to the east and south; wheat fields adjoin the base of the cone on the north and west. The east rim of the crater is about 150 feet higher than the
west rim. The rim is composed of pyroclastic material; the higher elevation of the east rim may be related to a prevailing wind from the west at the time of eruption, but erosion of the west rim has also played a significant role. The cone is about a quarter of a mile in diameter with a relief of approximately 200 feet on the east and 50 feet on the west. A trench, trending east-west, from which cinders have been extracted, extends through the south rim of the cone (Fig. 78). The pit is about 400 feet long by 100 feet wide. A maximum height of about 200 feet of cinders is exposed in the trench.

The cinders exposed are rudely bedded; a change in dip direction can be seen at the crater rim where the dip changes from inward to outward in respect to the crater. Angles of dip range from 20 to 30 degrees.

The cinders in the deposit are black to red with the black cinders overlying the red; under the microscope small crystalline feldspar inclusions are observed. Lapilli and scoria, composed of fragments 2 to 7 inches across make up the deposit. The cone is soil and grass covered but pyroclastics mantle the surface. Cinders are exposed at several places on the sides of the cone where cuts and other artificial openings have been made.

Chemical analyses of samples of red and black cinders from this locality were made in order to compare the composition of the two varieties of material. Table 25 shows the results of the analyses.

<table>
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<tr>
<th></th>
<th>Red cinders</th>
<th>Black cinders</th>
</tr>
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<tbody>
<tr>
<td>Fe₂O₃</td>
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<td>99.8</td>
<td>99.9</td>
</tr>
</tbody>
</table>
Volcanic cinders near Bancroft and Alexander, Caribou County

West of Soda Springs, in the vicinity of Alexander and Bancroft, there are several cones from which cinders have been extracted for local use, mostly as road surfacing material. These cones and pits were not visited.
Figure 71  Location Map of Volcanic Cinder Occurrences, Tps. 6, 7 and 8S, R 41E, Caribou County, With Generalized Geology
Fig. 72. View of soil-covered cinder cone, west of Little Crater, Caribou County.

Fig. 73. Photograph of commercial cinder pit, Sec. 26, T7S, R41E, Caribou County.
Fig. 74. Histogram showing size distribution of volcanic cinders, Shattuck Butte, Sec. 7, T3N, R37E, Bonneville County.

Fig. 75. Histogram showing size distribution of volcanic cinders, Sec. 26, T7S, R41E, Caribou County.
Fig. 76. View of Broken Crater, Secs. 8, 9, 10, & 17, T7S, R41E, Caribou County, looking southwest.

Fig. 77. View of Little Crater, showing symmetry of the cone, Sec. 34, T6S, R41E.

Fig. 78. Cinder pit and cinder cone, NW1/4 Sec. 14, T8S, R41E, Caribou County.

Fig. 79. Photograph of spatter cones found in Craters of the Moon National Monument, with cinder cone in the background.
PERLITE

INTRODUCTION

Perlite is a naturally occurring volcanic glass that expands on heating to yield a widely used, lightweight, frothy product; in commercial usage the expanded product is also referred to as perlite.

The construction industry consumes a major part of the perlite produced in the United States, but other uses are also significant. Sharps (1961, p. 5) lists the uses of perlite and the percent consumed in each application as follows: plaster aggregate, 60 percent; concrete aggregate, 13 percent; filter aids, 12 percent; oil well cement, 4 percent; loose fill insulation and other insulations, 2 percent each; soil conditioner, 2 percent; filler, paint additive and wall-board, one percent each; miscellaneous uses, 2 percent.

Perlite is not an important raw material in Idaho; at the time of this investigation (1963), the Oneida Perlite Corporation near Malad, in Oneida County, operated the only perlite mine and expanding plant in the state. A substantial deposit occurs near Sheaville in Oregon along the Idaho-Oregon boundary, but the major part of the deposit is in Oregon with only a slight overlap into Idaho. Considerable prospecting has been done on this deposit but no steps have been taken toward commercial development. Small lenses and pods of perlitic glass are often found associated with the silicic volcanic rocks so widespread in southern Idaho but, aside from the Oneida deposit, none of these are known to be economically significant.

USES

Perlite was first produced commercially in the United States in 1946; 4200 tons of perlite were produced that year from four mines in Arizona (Otis, 1960b, p. 581). Since 1946 the perlite industry has grown very rapidly, and in 1963, 270,000 tons of expanded perlite were sold at a value of 14 million dollars.

Plaster aggregates

The major use of expanded perlite is in plaster aggregate; this use consumes approximately 60 percent of the annual production. Perlite replaces the silica sand used in ordinary gypsum plaster and certain advantages are imparted to the product. Dead weight is reduced considerably because perlite plaster weighs about half as much. The resistance to heat transmission is increased and consequently insulating qualities are improved. Water requirements are less than for other lightweight plaster aggregates, such as pumice, and thus drying time is more rapid (Perlite Institute, 1961b).
Lightweight concrete aggregate

Perlite is used as concrete aggregate in applications where a high compressive strength is not required, but insulation against heat and sound, and lightweight, are important considerations.

The compressive strength of perlite concrete varies with the mix design and ranges from 20 to 70 pounds per cubic foot with mix ratios of 1 to 4 to 1 to 8, respectively; however, a weight of only 20 to 40 pounds per cubic foot, depending on the mix ratio, can be attained (Perlilte Institute, 1961a).

Some of the desirable properties of perlite concrete are its extremely light weight, insulating properties, fire resistance, durability and adaptability. Perlite concrete can be job or transit mixed, precast into panels or slabs, poured monolithically on flat, uneven, curved or sloping surfaces and it can be sawed and nailed.

Perlite aggregate permits a low water-cement ratio in the mix, yet the necessary workability is attained. Expanded perlite particles have a closed cellular structure and therefore much less absorption than a natural lightweight aggregate, such as pumice. Higher strengths at lower densities can be obtained in concrete with perlite aggregate.

Perlite is used for roof decks, insulating concrete and curtain wall construction in multi-story buildings.

Other uses

Filter aids are an increasingly important use of perlite fines. Controlled milling, close sizing and careful limitations of size ranges are required, but if these conditions are met, expanded perlite is an effective filtering medium (Otis, 1960, p. 584).

Oil well cementing and grouting are important uses of perlite and when used as an additive in drilling mud, it helps prevent loss of circulation (Mason, 1951, p. 15).

Expanded perlite is an excellent insulating material. It is used as loose fill insulation in the cavities of wall blocks or between wall studs in building construction. Preformed perlite is also used for insulating furnaces, steam pipes and in refrigeration (Otis, 1960, p. 584). The vessels used to transport and store liquid forms of oxygen, hydrogen and other gases at temperatures below -250°F require efficient insulation to prevent vaporization by conduction or radiation of heat. Expanded perlite has been found to be an effective cryogenic powder and can compete with calcium silicate, silica aerogel, diatomaceous earth and other materials commonly used for insulation of this nature. The importance of transporting cryogenic liquids (liquids at extremely low temperatures) is exemplified by the needs of liquid hydrogen in the missile field (M. L. Hess, personal communication, November, 1962).
Expanded perlite has been used as a soil conditioner with success. It makes the soil loose and pliable, allows it to receive and consume abundant moisture and permits aeration of the soil. It has been used as seedbeds for roof gardens, flower beds and potted plants.

Miscellaneous uses of perlite include paint filler and extenders, the manufacture of wallboard, a use that is increasing, and other uses.

The rapid growth of the perlite industry is not entirely because of its versatility and outstanding performance as a construction and insulating material. The Perlite Institute, Incorporated, a national organization whose supporting members are active in the perlite trade, has accomplished a great deal toward the successful promotion of perlite. This has been done by advertising, continuous research and development of new uses and technical assistance to producers and consumers of perlite.

**Competitive materials**

In all of its fields of application, perlite encounters competitive materials. Exfoliated vermiculite successfully competes with perlite as a lightweight plaster aggregate; pumice is also used as lightweight plaster aggregate, but it is not as widely accepted as perlite or vermiculite.

For lightweight concrete aggregate, expanded clay, shale and slag are highly competitive with expanded perlite and pumice. Volcanic cinders, exfoliated vermiculite and diatomaceous earth are also firmly established in this application. However, perlite produces what might be called a super-light concrete and it is used when extremely light weight is desired; vermiculite is its closest competitor in this respect.

Exfoliated vermiculite, pumice, diatomite and mineral wool possess insulating properties similar to those of perlite and these materials obtain a substantial share of the loose-fill market.

As a filtering agent, the principal competitive material is diatomite. As a filler and extender, many inert materials compete with perlite.

**MINING, EXPANDING AND ECONOMIC CONSIDERATIONS**

**Mining**

Perlite deposits must be thick and cover extensive areas in order to be exploited at a profit. Open-pit mining methods are used and overburden must be removed when present. In some deposits blasting is required, but in most instances
the rock is loosened with bulldozers equipped with scrapers. Excavation is done with carry-alls or other power equipment. Only those deposits that can be mined cheaply are exploited and open-pit methods require substantial volumes of material for economic operation.

**Expanding procedures**

The crude perlite is transported from the mine to a mill where it is crushed, screened and dried in preparation for expansion.

Screening and sizing are carefully controlled because the size distribution of the crude ore particles influences the expanding characteristics of the crude perlite (Otis, 1960, p. 583).

Crude perlite contains from 2 to 5 percent combined water and when the crude ore is quickly heated to a thermoplastic state, vaporization of the water takes place and the escaping steam produces bubbles in the perlite. A lightweight cellular product is the result. Before expanding, crushed and sized perlites have a bulk density of 65 to 75 pounds per cubic foot. The densities of expanded perlites, depending on the intended use, and the degree of expansion, are 3 to 20 pounds per cubic foot (Otis, 1960, p. 582).

The factors that influence expansion of crude perlite are (1) the amount of originally entrapped water present, (2) the amount of entrapped water retained when the softening temperature is reached, (3) the rate of heat application, (4) the maximum temperature reached, (5) the structure of the raw perlite including fractures, and (6) the size distribution of the crude ore particles furnace (Otis, 1960, p. 583).

The important temperature in expansion is one at which the glass is soft enough to be physically deformed by the expanding steam. This ranges from 1400°F for some perlites to 2000°F for others. A high frequency of parting planes increases the formation of fines. Some perlites explode on heating because of inherent weaknesses in the rocks (Otis, 1960, p. 583).

The production of a uniformly expanded product is often difficult and certain operative techniques have been developed. These techniques vary with different ores and operators. Preheating the feed to drive off ineffective water at 400°F to 600°F is practiced in most plants.

Two types of expanding furnaces are commonly used; these are the horizontal rotary furnace and the vertical furnace. There is disagreement among authorities as to which is the most efficient.
The fines are usually separated in a cyclone from the coarse material after expansion. Some plants are equipped with baghouses to collect dust escaping the cyclones. Most of the products, dust, fines and coarse, are marketed for a variety of specialized uses.

Economic considerations

The perlite industry is highly competitive; the reserves of raw material, market prices, transportation costs and quality of the product are especially important considerations in the evaluation of a deposit. Naturally occurring perlite is not a highly unusual substance, however, not all perlites expand and those that do may not be acceptable because they do not expand uniformly or proper particle shapes with strong cell walls are not produced.

To properly evaluate a perlite deposit the thickness and areal extent of the occurrence must be considered. The deposit should be adaptable to open-pit mining methods and overburden must not be excessive. Another important consideration, often overlooked, is the occurrence of non-expandable material in the deposit. Pods and lenses of unexpandable material such as tuff, lava or glass, may be closely associated with the perlite in a deposit and selective mining may be required, that, in open-pit operations, raises costs. Careful exploration by drilling and trenching is required.

Careful pilot plant tests must be made to evaluate the expanding characteristics and quality of the resulting product before commercial exploitation of a deposit is undertaken.

Most producers of perlite operate their own expanding plants but about two-thirds of the perlite mined is sold as raw ore to other expanding plants in the United States and Canada. In 1963, crude perlite was produced by 17 companies from 18 mines in 7 states. There were 77 companies operating 90 expanding plants in 30 states during 1963. The average value of crude perlite mined in 1963 was about $8.00 per ton while that of expanded perlite was $53.70 per ton.

Transportation costs are an appreciable factor in the price of perlite. Otis (1960, p. 586) remarks:

Crude perlite is produced in 6 western states, the eastern-most being Colorado. Transportation therefore plays an important role in the distribution of costs. In 1958 carlot shipments of crude perlite to the eastern seaboard from Colorado and northern New Mexico was about $13 per ton and from Nevada about $16 per ton, over 60 percent of the total delivered cost to expanders.
In addition to the cost of rail transportation of perlite, the cost of transporting the material from the mine to an expanding plant or a rail point is significant. A distance of 25 to 30 miles is probably the maximum that can be tolerated.

There is a tendency for the perlite industry to be controlled by a few major organizations. In 1961 there were 15 producing companies, 8 of these could be considered major producers. Any new company entering the perlite field needs some advantage over existing producers, in the way of freight rates or a superior product in order to gain a substantial share of the market. In recent years operating mines have overproduced, indicating that existing operations are adequate to fulfill the demand for perlite. In addition, known reserves are adequate for any foreseeable need (Otis, 1960, p. 585).

ORIGIN AND OTHER FEATURES OF PERLITE

Origin

Strictly speaking perlite is a variety of volcanic glass in which strain incident to cooling has produced a concentric or "onion" pattern of fracturing. This pattern of fractures is generally visible with the naked eye, but in some glasses it is visible only under the microscope. Perlitic texture thus refers to the concentric fracture pattern found in volcanic glass. In commercial usage perlite refers to any naturally occurring volcanic glass that will expand on heating to yield a frothy, lightweight product.

There are several varieties of volcanic glass. Among them are obsidian, perlite and pitchstone. Obsidian contains up to one percent chemically combined water, perlite from 2 to 5 percent and pitchstone, that has a greasy rather than a pearly luster, has up to 10 percent combined water (Sharps, 1961, p. 3). Most commercial perildes have a composition similar to that of rhyolite, with a silica content greater than 70 percent (Jaster, 1956, p. 376).

There is disagreement concerning the genesis of perlite. Jaster (1956, p. 378) says that perlite is a product of igneous processes and, with possible rare exceptions, it is not a product of any environmental effect subsequent to eruption. Sharps (1961, p. 3, 4) has discussed several concepts and theories regarding the origin of perlite. These are summarized briefly below.

One theory is that volcanic glass, containing 2 to 5 percent water at the time of eruption, was cooled rapidly, producing small, onion-like masses. The concentric fractures are thought to be the result of contraction or cooling. But, as several workers have pointed out, if the perlite contains enough water to expand on heating, how could it have solidified under atmospheric pressure without expanding? It was thought that pressure, brought about by intrusion under shallow overburden, or under water,
prevented expansion, but evidence of perlite formed from masses of lava that were erupted into the atmosphere, has discredited the theory of pressure preventing expansion. Hydrothermal alteration of pumice, tuff and other pyroclastic, glassy debris has also been cited as a possibility.

Sharps also notes the concept that perlite was formed from obsidian through the introduction of water vapor with the consequential development of perlitic structure. The water vapor could have been derived partly from a crystallizing rhyolite or from the surrounding country rocks.

Another current concept is that perlite is formed from obsidian by hydration. The water of hydration probably comes from rain, snow or ground water during a late cooling stage or at a still later time.

Williams and others (1955, p. 121-122) say that many of the fine-grained glassy rocks were evolved from magmas whose composition was close to that of eutectic mixtures of quartz and alkalic feldspar. These magmas, at temperatures near the eutectic point, tend to be extremely viscous so that crystallization is prevented or greatly impeded. Rapid chilling produces obsidian, perlites and pitchstones.

Williams and others go on to say that the wide variation in water content of these glasses is not understood. When a siliceous magma is erupted at the surface or intruded at shallow depths, it usually has a temperature between 600° and 850°C and can hold only a little water in solution. That is why such magmas chill to produce obsidian. The magmas that form perlites and pitchstones take up additional water by absorption as they cool. In some instances they imbibe water vapor from wet sediments or from lakes and seas into which they are discharged. Generally, however, perlites and pitchstones are intimately intermingled, as lenses and irregular streaks or pods, within holocrystalline lavas; presumably they represent fractions of quickly vitrified magma that absorbed water vapor expelled from the more slowly cooled holocrystalline fraction.

Jaster (1956, p. 376) points out that there is some controversy over whether the water in perlite is in a molecular state or is dissociated. Experiments show that upon heating water is released at a regular rate so that partial crystallization is not essential in the glass insofar as it concerns the water content. Sharps (1961, p. 3) presents evidence to show that the water responsible for expansion is not mechanically trapped in the perlite.

Physical properties and chemical composition

Volcanic glass may be essentially free of crystalline material, but generally they contain microscopic crystallites and other inclusions. Jaster (1956, p. 378)
notes that some glasses contain large phenocrysts or crystals which may range in proportion from a percent or so up to 50 percent or more in rocks known as vitrophyres.

Sharps (1961, p. 3) notes a study where it is shown that the microcrystalline development of peraltes is divided into two parts. The first, a primary phase, comprised of crystallites and microlites is a trait of all hypocrystalline rocks. The second phase is a secondary effect produced by devitrification whereby glass is converted to crystalline material. Because all glasses are unstable they tend to devitrify with time and few occurrences of undevitrified glass are known that are older than Cretaceous. This is also why commercial perlite deposits are confined to the western United States. As pointed out by Jaster (1956, p. 378) the recognition of crystals and devitrification products is critical in the evaluation of a perlite deposit, as the presence of any of these materials beyond certain low limits will make a deposit unsuitable for commercial purposes.

Peraltes are rocks and not minerals and therefore they have no fixed theoretical chemical composition. Anderson and others (1956, p. 5) published analyses of 10 commercial peraltes from the western United States. The range of values found by these analyses is given in Table 26.

**TABLE 26 - Chemical analyses of peraltes ores, range of values in percent (After Anderson and others, 1956)**

<table>
<thead>
<tr>
<th>Moisture</th>
<th>CaO</th>
<th>Loss on ignition</th>
<th>MgO</th>
<th>SiO₂</th>
<th>Na₂O</th>
<th>Al₂O₃</th>
<th>K₂O</th>
<th>Fe₂O₃</th>
<th>SO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1-0.6</td>
<td>0.5-1.0</td>
<td>3.3-4.9</td>
<td>0.1-0.3</td>
<td>71.2-74.4</td>
<td>2.9-4.1</td>
<td>12.4-14.0</td>
<td>4.0-5.0</td>
<td>0.5-1.5</td>
<td>0.0-0.2</td>
</tr>
<tr>
<td>0.03-0.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Volcanic glass may show a variety of physical characteristics. Colors range from black to nearly white and they may be red, green or brown (Jaster, 1956, p. 378). Most perlitic glasses are gray to grayish black. Some dense varieties of glass, like obsidian, break with conchoidal fracture; varieties of volcanic glass other than peralite, like pumice, volcanic ash and welded tuff, generally expand on heating and in commercial usage any of these that will expand to a marketable product are considered peraltes.

The specifications for expanded peraltes vary with the different uses and they are available from the American Society for Testing Materials. The specifications deal mainly with size gradations and unit weight, they are not listed here.
THE PERLITE INDUSTRY IN IDAHO

Production and value

Because the Oneida Perlite Corporation at Malad in Oneida County is the only organization in Idaho that is active in the perlite industry, annual production figures are not published. The remarks that follow are taken from the U. S. Bureau of Mines Minerals Yearbooks.

In 1960 the Oneida Perlite Corporation began development of the deposit. In 1961 production was established and bulk shipments of crude ore were made to expanding plants in the western United States and Canada. Some of the crude perlite was expanded at the company-owned expanding plant at Malad, and the product was used for plaster aggregate, concrete aggregate, soil conditioner and insulating material. Operations were much the same in 1962 except that production of crude perlite was 3 percent greater than in 1961. In 1963 the quantity of crude perlite produced dropped sharply as compared to 1962, however, the amount of crude perlite expanded in the company plant increased over 1962.

Idaho seems to be at a disadvantage in regard to location. The following is quoted from correspondence with the U. S. Gypsum Co. (F. C. Appleyard, personal communication, February, 1963):

Idaho is at a disadvantage location-wise, in that the major perlite markets are in the midwest and east. Most perlite production now comes from New Mexico or Colorado (which have the lowest freight rates to the east) or Nevada-California which are the closest to the west coast markets. Average price, f.o.b. mine, of crushed and graded perlite ore is in the $7 to $9 per ton range. This material is all minus 10 mesh and has a minimum of minus 100 mesh fines, the standard size, ready for expansion....

Because of the disadvantages of location, limited local markets and the lack of abundant deposits, there is little chance that perlite will become an important commodity in the state.

Mining laws applicable to perlite

Perlite is not included as a common variety of stone and is not affected by Public Law 167 (Multiple Use of the Surface Act of 1955), that prohibits the location of a mining claim by reason of discovery of common varieties of sand, stone, gravel, pumice, pumiceite or cinders. Perlite that occurs on the public lands may be located as a mining claim by "discovery."

Perlite deposits on state-owned land are subject to lease from the State Land Board.
PERLITE DEPOSITS IN IDAHO

Perlrite, Oneida County, Sec. 25, T11S, R35E

The Oneida Perlite Corp. of Malad City, has mining claims located in Secs. 23, 24, 25, 26, 33, 34, and 35, T11S, R35E. These claims cover an extensive perlite deposit along Wrights Creek about 25 miles north of Malad City in Oneida County. Most of the mining activity has been in Sec. 25, T11S, R35E, but pits, cuts and natural exposures are widespread in the area. A crushing and screening plant is located at the mine.

In general the perlite is light gray to white in outcrop and perlitic structure is well developed. The outcrops are massive and the material is somewhat brittle (Fig. 80).

A tentative stratigraphic column for the perlite area has been worked out as follows (Staley, 1962, p. 2):

Lake beds—sand, silt and gravel
----------Unconformity----------
Basalt
Water-laid mixture of pumice and perlite
Flow-banded perlite and rhyolite with
some intercalated water-transported perlite detritus
Perlite sand (local)
Massive perlite in large mounds
Silt, water-laid, underlying the massive perlite
----------Unconformity----------
Paleozoic sedimentary rocks

The perlite grades laterally into ordinary flow rocks indicating that some special set of local conditions existed at the time of its formation. Rhyolitic rocks associated with the perlite are exposed north and northeast of the deposit. Basalt can be seen on some of the higher elevations to the south.

In Secs. 25 and 26, pits, trenches and outcrops expose perlite over an area about 1 1/2 miles long, northeast-southwest, by half a mile wide. Other perlite exposures can be seen in Secs. 24 and 33, T11S, R35E and in Sec. 19, T11S, R36E. Wagon-drill holes have shown the perlite to extend to depths of at least 50 feet below surface outcrop; 50 feet was the limit of the drill. There is a remarkable lack of waste, or unexpandable material like obsidian or lithoidal rhyolite in the massive perlite.
Fig. 80. View of perlite pit showing massive perlite outcrop. Oneida Perlite Corporation deposit, Sec. 25, T11S, R35E, Oneida County.

Fig. 81. View of gravity flow mill for crushing, screening and drying perlite. Oneida Perlite Corporation, Sec. 25, T11S, R35E, Oneida County.
It has been pointed out (Staley, 1962, p. 3) that the water-laid silts lying below the perlite are indicative of the origin of the deposit. It is postulated that where rhyolite flows blanketed wet silts obsidian was probably formed by rapid chilling of the molten lava. The wet sediments would also be a source of the water of hydration necessary for the formation of massive perlite from the obsidian.

The mining, milling and expanding operations have been described in some detail by Staley (1962). The following comments regarding mining and processing are mostly taken from this publication.

The perlite is mined by open-pit methods with shovels, trucks and bulldozers. Drilling and blasting are seldom required.

The raw ore is crushed and screened in a gravity flow mill near the mine (Fig. 81). A horizontal, low-temperature, gas-fired kiln is used for drying the crushed and screened products. A belt conveyor system distributes the various sizes to six 150-ton steel storage bins. The capacity of the plant is 30 to 40 tons of raw ore per hour. The plant is also equipped with a dust control system.

The dried and screened product is trucked to expanding and storage facilities located on a railroad spur at Malad City about 25 miles distant. Six, 200-ton, steel storage bins are provided for storage and blending of raw material. The bins are equipped with belt conveyor systems for discharging the bins into trucks or for direct loading into railroad cars for bulk shipments of raw ore.

The raw material is trucked from the storage bins to the expanding furnace. The furnace is a gas-fired, horizontal type. It has a capacity of about 120 bags of perlite per hour and a daily capacity of 720 bags. Automatic bagging machinery is also provided. The furnace is housed in a warehouse near the railroad spur; the warehouse also provides space for storing the expanded and bagged products.

Six sizes of expanded material are produced to meet the varied demands of consumers. A dust-collecting system gathers the extremely fine material. Plans for the production of a filter-aid product, utilizing the fines, have been discussed by the company.

Raw ore has been shipped to expanding plants in Canada, Illinois, Washington, D. C., Indiana, Iowa, Ohio, Minnesota and other localities (Staley, 1962, p. 7). The expanded product, marketed under the trade name "Perlicor" is used in West Coast markets.

Five of the expanded products are bagged in three cubic foot bags, the others in 3 1/2 cubic foot bags. Horticultural perlite is distributed in small bags.
Fig. 83. View of outcrop area, Ben-Jel bentonite deposit, Sec. 20, T5S, R1E, Owyhee County. Processing mill in background.

Fig. 84. Bentonite outcrop, Ben-Jel bentonite deposit, Sec. 20, T5S, R1E, Owyhee County. Note lack of vegetation and characteristic pattern of shrinkage cracks.

Fig. 85. Bentonite outcrop, Sec. 28, T21N, R22E, Lemhi County. Shows characteristic appearance of bentonite in outcrop.
Figure 82 Sketch Map of Perlite Occurrence, Sec. 7, T3N, R3E, Ada County.
The deposit was estimated to contain 6,200,000 tons of easily mineable ore, as much or more indicated ore, and an unknown amount of probable ore in 1960, when exploration and development were completed (Staley, 1962, p. 2). The perlite occurs in a variety of types and sufficient variation is present to satisfy almost any market demand (Staley, 1962, p. 2).

**Perlite, Ada County, Sec. 7, T3N, R3E**

There are several small lenses of perlitic glass intermixed with flow-banded rhyolite near the mouth of Picket Pin Creek in northeastern Ada County. The principal outcrops of perlite are found at the confluence of Picket Pin and Cottonwood creeks and farther up Picket Pin Creek to the east. The best exposures are in Sec. 7, T3N, R3E (Fig. 82).

In the area under discussion an isolated exposure of acidic volcanic rock occurs that has been correlated with the Owyhee Rhyolite of Tertiary age (Savage, 1958). Picket Pin Creek has cut a canyon through these acidic rocks, and lenses and pods of perlitic glass within the rhyolite are exposed. Granitic rocks crop out east of the rhyolite and probably underlie it. Elsewhere in the vicinity sand and clay beds of the Idaho Formation crop out.

The perlitic glass is black to gray and the typical "onion" texture is well displayed in hand specimen. When heated, the perlite expands into a frothy product composed of spherical particles.

The lenses of perlite are generally less than 100 feet in diameter. Farther up Picket Pin Creek, above its junction with Cottonwood Creek, tuffaceous material, composed of flat, angular shards of volcanic glass and minor quartz grains and mica flakes overlies the rhyolite. The tuff contains fragments of perlite and rhyolite. There is a similar outcrop of tuff near the mouth of Picket Pin Creek that also contains fragments of perlite and rhyolite.

The lenticular nature of the perlite and the amount of rhyolite overlying it indicate that the deposit is of little commercial importance. However, the associated rhyolite with its intricate flow banding composed of sinuous, purple and dark glassy bands in a lighter groundmass might have some value as a decorative building stone.

**Perlite, Owyhee County, Sec. 2 and 11, T4S, R6W**

A deposit of perlite is located about 2 miles east of Sheaville, Oregon on the Idaho-Oregon boundary. The greatest part of this deposit is in Oregon; only a small part is within Idaho. The deposit is in the Cow Creek drainage basin in Secs. 24 and 25, T28S, R46E and Secs. 19 and 30, T28S, R47E (Willamette Meridian). The small part that extends into Idaho is in Secs. 2 and 11, T4S, R6W (Boise Meridian). Access to the deposit is from Sheaville, Oregon.
The locality is in a broad basin about 1,500 feet wide. It appears that a pre-existing valley was filled by a rhyolitic flow. An older basalt, that can be seen protruding through the younger rhyolite at places, was evidently covered by the rhyolite.

The rhyolite has a high glass content and it contains lenses of perlite, up to 50 feet thick, volcanic ash and tuff. Ribs of highly siliceous rhyolite are encountered as well. The rhyolite shows highly contorted flow structures.

A private mining firm estimated there are over 1,000,000 tons of perlite available at this locality. The estimate was based on detailed mapping, sampling and drilling. Overburden is less than 3 feet. The bulk of the perlite occurs in two ore-bodies that are aligned in a northerly direction. A small portion of the northern ore-body is in Idaho, but this part probably makes up less than 5 percent of the entire tonnage.

Pilot plant tests on the ore show that the perlite is expandable but the expanded particles are fractured and lack structural strength. In addition the nearest rail point is at Marsing, Idaho, a distance of some 42 miles, a haulage distance that is considered excessive for a low-value product like perlite. It is also probable that selective mining would be required to avoid the siliceous rhyolite ribs, ash and tuff associated with the perlite. Selective mining would create unreasonable mining costs. Because of the above factors it is doubtful if development of this property would be feasible under present conditions.

**Perlite, Owyhee County, Sec. 8, T4S, R2W**

An occurrence of perlitic glass is found west of Murphy on the Silver City road in Owyhee County. It is located in Sec. 8, T4S, R2W about 1 1/2 miles east of the Sinker Creek bridge.

The perlite is associated with flow-banded, glassy rhyolite. The rhyolite is the predominant rock type in the area; it crops out extensively north and west of the perlite occurrence. The various bands are contorted into intricate patterns with contrasting colors. Colors vary from shades of red and brown to purple. Because of its unusual appearance the rhyolite would probably have some value as a building stone.

Volcanic glass is exposed as lenses included in the surrounding rhyolite at several places in the vicinity of the occurrence. The lenses are generally of limited extent. The most extensive outcrops are southeast of the road along a gully where erosion has cut down through the rhyolite and exposed the included glass. A greenish-yellow clay is associated with the glass at several places as an alteration product. The lenses, as exposed, are generally less than 100 feet long by 25 feet wide and 10 to 15 feet thick. Some trenching or other means of exploration might prove some
INTRODUCTION

Bentonite is not an economically important commodity in Idaho. During the course of this investigation several occurrences of impure bentonitic material were encountered that are used locally for such purposes as lining canals and ponds to prevent leakage. Material from one deposit in Owyhee County has been used successfully as an oil-well drilling mud.

Because of the lack of important bentonite deposits in the state a detailed discussion of the subject is not presented. A few remarks briefly summarizing some of the more important considerations are given, followed by a discussion of the occurrences visited.

GENERAL REMARKS CONCERNING BENTONITE

According to Grim (1953, p. 361) the term bentonite was first applied to certain clays that occur near Fort Benton, Wyoming. The clays are generally highly colloidal and plastic; they have the characteristic of swelling to several times their original volume when placed in water, and they are composed chiefly of the montmorillonite clay minerals. The clays were derived from the alteration of volcanic ash in place. The term as used today refers to any clay with the above properties regardless of origin; but most occurrences of bentonite are derived from the alteration of volcanic ash, and only rarely are they found to be of different origin. Bentonites vary in color; white to gray is the most common, but pink, lavender, pale blue, pale green and even pure white are found (Anonymous, 1955, p. 1). The material has a dull, powdery appearance but when it is freshly broken it has a waxy luster and a soapy feel. Bentonite outcrops are characterized by lack of vegetation and they develop a characteristic "jig-saw puzzle" type of surface because of the development of polygonal cracks due to alternate wetting, swelling, drying and shrinking (Fig. 83). Most commercial deposits are of Cretaceous or Tertiary age.

Montmorillonite is the chief constituent of bentonite. This group of clay minerals includes the following:

- montmorillonite (hydrous magnesium aluminum silicate)
- beidellite (hydrous aluminum silicate)
- saponite (hydrous iron aluminum silicate)
- nontronite (hydrous iron aluminum silicate)
- hectorite (hydrous magnesium lithium silicate)
of the lenses to be more extensive. The appearance of the material in hand specimen ranges from typical black obsidian to grayish black glass with perlitic texture. A bluish tint can be seen on some of the perlite specimens.

A few bulldozer cuts have been made in the overburden surrounding the perlite outcrops but none are of sufficient depth to expose rock in place.

The lenticular nature of the glass would make exploration or mining difficult and expensive. Selective mining would be required to avoid inclusion of excessive amounts of waste. The limited indicated tonnage and adverse mining conditions, coupled with a 30-mile haul to the nearest railpoint at Marsing, would tend to make this deposit uneconomic.
related to the grade of the material being mined. According to Gillson (1960, p. 89), high-grade Wyoming bentonite is strip mined from beds 2 to 3 feet thick under more than 25 feet of overburden, with long truck haulage to processing plants.

Gillson (1960, p. 89) describes the processing procedure practiced in Wyoming deposits. As mined the bentonite contains from 30 to 42 percent combined water and this must be reduced to 6 or 8 percent to permit fine grinding to 200-mesh. Following grinding the material is bagged and it is ready for shipment.

A few of the considerations involved in developing and marketing bentonite are listed below (Anonymous, 1955, p. 2):

1. Size of deposit (high tonnage - low profit per ton type of operation)
2. Nature of the crude bentonite (different levels or parts of the same deposit may have different properties such as variation in color, colloid content, ease of hydration and others)
3. Cost of mining (open pit or underground)
4. Specifications demanded by buyers (most consumers desire a homogeneous product that will remain uniform)
5. Cost of treatment (removal of impurities; for example, sand, gypsum, carbonate matter, and soluble salts that have to be removed by washing)
6. Location of possible markets (shipping costs)
7. Price obtained for product

Idaho is not strategically located in respect to markets nor are any high-grade, extensive deposits of bentonite known.

The U. S. Bureau of Mines reported that a small tonnage of bentonite was produced from the Ben-Jel deposit in Owyhee County in 1956, 1957 and 1958.

**BENTONITE DEPOSITS IN IDAHO**

**Bentonite, Owyhee County, Sec. 20, T5S, R1E**

The Ben-Jel bentonite mine is about 1 1/2 miles west of Castle Creek in the SW1/4 of Sec. 20, T5S, R1E. The deposit is located near the east end of a wide erosional basin trending east toward Castle Creek (Fig. 83). On the west and north steep to vertical cliffs of sand, silt and clay form the boundary of the basin. The
These clay members vary in composition principally by the exchange of sodium and calcium ions for the other elements normally present. Montmorillonite is one of the three-layer clay minerals, composed of silicon-oxygen sheets with aluminum-oxygen sheets between them.

The ability to swell when placed in water is a peculiar property of sodium bentonite. Wyoming bentonites may absorb five times their weight or 15 times their dry volume (Anonymous, 1955, p. 1). The swelling occurs when water enters between adjacent sheets of the sodium bentonite crystal and the lattice expands in one direction. The expansive properties of the lattice are related to the exchangeable atoms calcium and sodium. The presence of sodium favors extreme swelling while calcium reduces it (Smoot, 1962, p. 8). Thus two varieties of bentonite are recognized; swelling and non-swelling. The Wyoming (sodium) swelling bentonite has the widest variety of uses but non-swelling varieties are more suitable in some applications than are the swelling varieties.

Smoot (1962, p. 2) points out that the market for bentonite is highly diverse, consisting of many different economic uses, and the market within each general use varies considerably. Thus the final evaluation of bentonite for a single application depends on very detailed testing; field evaluation is generally unsatisfactory. Such features as the mineralogical make-up, cation exchange capacity, chemical analysis and thermal reactions along with physical testing of its thixotropic, swelling, dispersion, plasticity, absorption and surface activity properties are most useful for preliminary evaluation.

Samples were taken from the deposits of bentonitic material visited in connection with this investigation, but elaborate tests were not performed. Microscopic examinations of the materials were conducted a few simple tests noting the effect of immersion in water on the samples were made and differential thermal analyses of a few selected samples were performed.

As noted above the uses of bentonite are diverse. The principal use of swelling bentonite is in oil-well drilling mud where it serves as a suspending agent for drill cuttings and the heavy components of the drill fluids such as barite (Anonymous, 1955, p. 2). The use of casing can sometimes be avoided with application of a good drilling mud.

The major industrial uses of bentonite are for molding sands in foundries and steel works, drilling mud, oil refining and other uses (Gillson, 1960, p. 90). Non-swelling (calcium) bentonites find their major use in oil refining as a catalyst and decolorizing agent (Anonymous, 1955, p. 2).

Because of the varied uses and many grades of bentonite its value is highly variable. The mining and transportation costs that an operation can withstand are directly
A differential thermal analysis of one sample from the Ben-Jel deposit indicates that the material has the three-layer crystal structure of montmorillonite, that the order of stacking and organization of the crystals are good and that the exchangeable cation may be potassium rather than sodium (Fig. 86). It should be pointed out that an analysis of only one sample is not conclusive as to the make-up of the entire deposit.

**Bentonite, Custer County, vicinity of Mackay**

Kirkham (1927, p. 41) states that bentonite occurs near the railroad south of Mackay where it is very pure and white, and that it occurs in the Salt Lake Formation, interbedded with Late Tertiary lava flows.

A thorough reconnaissance of the area around Mackay was undertaken but little bentonite was found. In the southwest corner of Sec. 2, T6N, R24E, near the Houston Cemetery, west of Mackay, a small pit exposes massive clay-like material. This locality is the only place where such material was found in the Mackay area. The pit is west of the Alder Creek road at the base of the foothills.

The pit is about 50 feet by 100 feet; it exposes clay through a vertical distance of 25 feet. In appearance the material resembles highly altered rhyolite or tuff; it is white with streaks of brown material cutting through it. The clay occurs as lumps 2 to 3 inches across; it is soft and friable.

The deposit lacks the characteristic shrinkage crack pattern of most bentonite deposits; it slakes rather than expands in water. The only exposure is in the pit; the surrounding area is soil-covered, one to 6 feet of soil overlies the clay.

As mentioned previously, no other clay deposits were found in the area, but it is not certain that this is the clay referred to by Kirkham. A thorough search of the region might disclose a deposit of high-grade bentonite, but none could be found during this investigation.

**Bentonite, Lemhi County, vicinity of Salmon**

Thin beds of bentonite a few inches to several feet thick occur in the Carmen Formation of Tertiary age. The formation is confined to the intermontane Salmon basin and covers fully half of the Salmon quadrangle. The Carmen Formation is lacustrine; it is made up of detrital material derived from the surrounding region (Anderson, 1956, p. 29). Shale is the dominant rock type but sandstone is common and locally conglomerate and lignite occur. In places thin bentonitic shales and clays are intercalated with beds of siliceous shale and sandstone. Downslope creep causes these bentonitic beds to appear to be much thicker than they are; where bentonite occurs it generally mantles the entire hillside and conceals the underlying material. A characteristic pattern of shrinkage cracks develops on the bentonite and outcrops are devoid of vegetation.
basin floor is mantled by uncompacted, fine sand and very fine powdery clay. Several shallow gullies traverse the basin but relief is fairly low. The alluvial cover and low relief prevent an accurate determination of the depth and areal extent of the bentonite.

Bentonite has been extracted from a small open pit on the property. In the vicinity of the pit, located near the east end of the basin, bentonitic clay is exposed over an area about 700 feet by 500 feet. The bentonite is probably more extensive but alluvial material covers most of the area. Several drill holes are in evidence 25 to 50 feet from the periphery of the pit, but the information obtained by drilling is not available for this report. As near as could be determined from observations in the pit, the bentonite bed is about 15 feet thick. According to Powers (1955b) the bentonite bed is 35 feet thick. The bentonite appears to dip slightly east. Hard siliceous volcanic tuff underlies the clay; volcanic tuff also outcrops west of the pit on a low ridge separating two dry gullies.

The bentonite is the swelling variety. It is yellowish gray on a wet surface and white when dry. The outcrop has developed an intricate pattern of shrinkage cracks in response to alternate wetting and drying (Fig. 84). The pattern is well shown on the surface near the pit. Gypsum crystals are widespread in the bentonite and in the surrounding alluvium. Much of the overlying material is a fine, powdery clay that probably contains an appreciable amount of volcanic ash. Further exploration by drilling or trenching, particularly east of the pit, might disclose a larger volume than is now indicated.

A small hammer mill is situated at the pit and there are facilities for bagging the milled bentonite. The material is easily extracted with a front end loader. E. N. Bennett, of Nampa, Idaho is the mine owner (Personal communication, January, 1963). He stated that the bentonite has found local use as a waterproofing material for ditches and concrete structures. It has also been used as a drilling mud in exploratory oil-drilling operations in eastern Oregon. The material was found to be suitable to a depth of 7,000 feet, the maximum depth drilled using this clay. Another possible use, indicated by E. N. Bennett, is in forest fire control. According to information received from the U.S. Forest Service, they make extensive use of bentonite clay as a fire retardant dropped from low-flying aircraft as a slurry (E. R. De Silvia, personal communication, December, 1963).

The U. S. Bureau of Mines reported in 1956 that a small production came from this deposit. It was marketed locally for sealing potato cellars and a small quantity was marketed for rotary drilling mud (Baber and others, 1956, p. 366). In 1957, a small production was reported that was used in rotary drilling muds and for sealing irrigation canals and ditches (Baber and others, 1957, p. 366). In 1958 a small amount was used as a rotary drilling mud, but production was less than in 1957 (Baber and others, 1958, p. 302).
Sec. 28, T21N, R22E

Bentonitic clay has been mined from a pit on the east slope of Hot Springs Creek about 1 1/2 miles east of Highway 93 and about 1,500 feet north of the Salmon Hot Springs road.

An estimated 2,000 cubic yards of material have been extracted from a circular pit on the slope of a ridge paralleling Hot Springs Creek. The bentonitic bed appears to be about 15 feet thick. Indurated tuff and shale are associated with the clay. The deposit is difficult to evaluate because bentonite with a characteristic shrinkage crack pattern mantles the hillside and conceals contacts and underlying material (Fig. 85).

Samples were taken from the bottom of the pit up the east slope for 34 feet as follows:

Lemhi #5 - Light gray to white, hard blocky clay 6'
Lemhi #6 - Dark greenish gray, thinly laminated, clayey shale 4'
Lemhi #7 - White, fine-grained clayey sandstone 4'
Lemhi #8 - Light, hard tuff, gypsum at base - includes a 1-foot bed of purplish shale 7'
Lemhi #9 - White tuff from #9 to top of hill, clayey shale and tuffaceous material resembling Sample #8 (not sampled) 12'
Sample #8 (not sampled) 50' est.

Exposures are too poor to get a reliable attitude on the bedding but it appears to be horizontal. About 1,000 feet east of the open pit a discovery pit discloses a 3-foot bed of bentonite dipping 22°NW and striking N20E. The bentonite at the discovery pit is overlain by fine-grained, hard, siliceous sandstone and underlain by thin-bedded carbonaceous shale.

About 1,500 feet west of the mine, along the Salmon Hot Springs road, a site for a crushing plant can be seen. Almost all the equipment has been removed, or dismantled, but it appears that a cone crusher and ball mill were used at this plant for processing the clay.

The samples listed above were investigated in the laboratory. Sample 5 expanded slightly in water; detrital sand grains were abundant with a few shards of volcanic glass. Sample 6 swells to about three times its original volume in water; it contained volcanic glass and other detritus and abundant carbonaceous material. The sample represents a bentonitic shale. Sample 7 was not bentonitic. Sample 8 was only slightly bentonitic, it was made up of altered glass shards and clay.
According to Anderson (1956, p. 100), the bentonite beds in the Carmen Formation are sedimentary in origin and not the direct product of ash falls. They probably represent sediments derived from erosion of tuffaceous material in the Challis Volcanics. The clay is montmorillonite, mixed with considerable silt and sand.

Bentonite occurrences at two localities near Salmon were investigated. Prospecting in the Carmen Formation would undoubtedly reveal other localities similar to those discussed below. Although the beds are relatively thin, they are extensive laterally and represent a substantial reserve of impure bentonite, which has been found effective as a liner for canals to prevent leakage; a use which might be expanded. To date ditch-lining has been the sole use of this material.

Sec. 23, T21N., R22E

Bentonite has been mined from a small pit about 5 miles southeast of Salmon near Highway 28 about a quarter of a mile northeast of the highway. The locality is situated on the steep east slope of the Lemhi River at the base of the foothills bordering the river. Near the top of the slope there are several thin beds of bentonitic clay, interbedded with hard, siliceous sandstone. The remainder of the slope, about 75 feet, is covered by loose clayey soil derived from the upper bentonitic beds. When the bentonite becomes wet it swells and tends to creep downslope, mantling the hillside below. A pit with a 25-foot face has been excavated at the base of the hill. The pit is in grayish-white, clay-like material.

The entire series is white to light gray. The bentonite is grayish green, and it contains abundant gypsum crystals. Tuff, sandstone and conglomerate make up the bulk of the material present. The sandstone is fine to coarse with included quartz pebbles.

The beds are about horizontal. If extensive mining were undertaken and a reasonably pure clay product was desired, overburden removal would be a problem on the lower beds. In many instances the relative purity of the product when used for ditch lining is not important so long as enough bentonite is present to effectively seal leaks.

Samples were taken from the bentonite near the top of the slope and from the pit at the base. All of the clay samples swell to some extent, generally to about three times their original volume, but the resulting gel is easily dispersed. Most of the samples are highly contaminated with quartz grains, mica flakes and gypsum crystals.

Differential thermal analyses of two samples show that they bear a general resemblance to the montmorillonite group clays, but the order of stacking and organization of the crystals are poor (Fig. 86). Most sediments containing montmorillonite generally give similar results (Rowland, 1955, p. 156).
cover. If this material is the bentonite Kirkham refers to, it covers a respectable area and is worth further investigation, but it appears to be mostly calcareous clay. This material has been used locally as an irrigation ditch liner.

Bentonite, Clark County, Sec. 3, T9N, R33E

About a half mile west of Lidy Hot Springs and a mile north of State Highway 22, in Clark County, there is a pit and loading platform where clay has been mined from a bulldozer cut. The material resembles common clay and it has a high calcium carbonate content; the material effervesces vigorously with HCl. The bulldozer cut is about 75 feet long and exposes clay through a vertical distance of about 35 feet.

Near the base of the cut there are about 4 feet of green to white clay striking N25E and dipping 55E. Underlying this green to white clay there are 3 feet of green plastic clay. The upper part of the cut exposes a white clayey rock resembling altered tuff; the rock weathers to a grayish brown, lightweight, powdery material.

About a quarter of a mile east of the loading platform another cut exposes clay which also has a high lime content; about 25 feet of material is exposed. The clay is similar to that farther west.

Fresh-water limestone and acidic tuffs crop out in the surrounding area. These exposures lie in the foothills on the north edge of the flat, alluvial-covered, Snake River plain, that extends south and parallels the foothills.

Based on physical appearance and preliminary tests, if this clay is bentonite, it is very impure. It is used locally for lining irrigation ditches to prevent leakage and it evidently has a high enough clay content to be effective in this application. Some of the material in the clay may be bentonitic but most of it is marl or highly calcareous silt.

A differential thermal analysis of a sample taken from a stockpile at the loading chute shows the material to be predominantly calcite (Fig. 86).
aggregates with some detrital sand, mostly quartz grains. In water the material swelled only slightly. Sample 9 was composed of clay aggregates and flattened glass shards, this sample slaked in water. From the location of Sample 9 to the top of the slope the material is similar to material at Sample 8.

A differential thermal analysis of Sample 6 indicates that this material is similar to the clay found in Sec. 23, T21N, R22E, discussed above. The clay represents an impure montmorillonite (Fig. 86).

**Bentonite - Clark County, Approx. Sec. 2, T9N, R33E**

There are reportedly large reserves of bentonite west of Dubois in Clark County. According to Kirkham (1927, p. 42):

...about 15 miles from the railway west of Dubois, there is an enormous tonnage of this material (bentonite) underlying fresh water limestone. At this place the outcrop is several hundred feet long and probably averages 15 feet thick. The bentonite here, which is, of course, impure at the weathered, soil-covered surface, seems to be pure enough for commercial uses and has a soapy yellow color. The haulage problem for this deposit at present will probably null its value. Prospecting in the acidic-lava covered regions near the railway is almost certain to discover other deposits of this unusual clay.

A reconnaissance of the area around Lidy Hot Springs, which is about 15 miles west of Dubois, was made to investigate this bentonite occurrence. About three quarters of a mile north of the Lidy Hot Springs swimming pool, an abandoned tunnel through a hillside exposes about 10 feet of clay overlain by 3 to 4 feet of limestone. The clay-limestone contact dips slightly south. This clay is fine-grained and white. It breaks down to a granular aggregate in water leaving a residue of sedimentary particles and clay aggregates. It resembles an impure kaolin more than it does a bentonite.

About a quarter of a mile north of the tunnel a pit exposes about 10 feet of white to green clay overlain by soil. The clay beds strike N40E and dip 35E. The material exposed in this pit is a calcareous clay or marl. It effervesces strongly with hydrochloric acid and breaks down in water leaving a residue of rounded sand grains and clay aggregates. Small glassy crystals of calcium carbonate can be seen in the clay with a binocular microscope.

In this area, north of Lidy Hot Springs, the clay exposures do not have the characteristic appearance of bentonite outcrops. Vegetation mostly sagebrush and short grass, grows on the outcrops and the usual mud-crack pattern is lacking. The clay in the pit is overlain by about 2 feet of soil which may account for the vegetative
**Figure 86**: Differential Thermal Analysis Curves Of Bentonite And Bentonitic Clay.
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_________, 1959d, Tentative specifications for lightweight aggregates for concrete masonry units, ASTM Designation: C331-59T.

_________, 1960, Tentative specifications for lightweight aggregates for structural concrete, ASTM Designation: C330-60T.


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________, 1961, Specifications for pozzolans.


## APPENDICES

SCREEN ANALYSES OF VOLCANIC CONSTRUCTION MATERIALS

**APPENDIX - A**

**PUMICE**

(Shing Hsu, Analyst)

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APPENDIX - B - PUMICITE  
(Geo. Hsu, Analyst)

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