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PUMICE DEPOSITS OF THE KLAMATH INDIAN RESERVATION KLAMATH COUNTY, OREGON

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ABSTRACT

A large volume of pumice is widely distributed over the Klamath Indian Reservation in "flow" and "fall" deposits. The flow material on the Reservation is restricted to the area west of Klamath Marsh, and the fall material is thickest immediately southeast of the Marsh.

Tests of the chemical and physical properties of the pumice indicate that the pumice is suitable, with some limitations, for use as an aggregate and as a low-grade abrasive. Preliminary examination also indicates that with proper processing it may have a potential use as pozzuolana. The pumice is similar to material now being marketed for lightweight aggregate in Oregon, but processing of the pumice is necessary to obtain a suitable size distribution of the particles.

INTRODUCTION

During two weeks in October 1950, a field investigation of the pumice deposits of the Klamath Indian Reservation, Klamath County, Oreg., was made by geologists of the Geological Survey. Samples of the various types of pumice in the area were collected and tested in the laboratories of the Geological Survey and the Bureau of Reclamation to determine their physical and chemical properties in order to ascertain their suitability for commercial exploitation. Much of the detailed geology presented in this report has been summarized from published reports by Diller and Patton (1902), Moore (1937), and Williams (1942), which contain descrptions of the geology of the area as well as detailed data on the properties of the pumice.

An evaluation of the pertinent geologic and economic factors related to the profitable utilization of the pumice is presented in this report. The evaluation has special reference to the possibilities of commercial exploitation of the pumice for use as (1) lightweight aggregate, (2) pozzuolana, and (3) abrasive material.

Mr. Bitney, Mr. E. J. Diehl, Mr. H. J. Thoreson, and Mr. F. W. Parker of the Bureau of Indian Affairs made valuable suggestions for the investigation of the pumice deposits and were helpful in many ways during the field work.

GENERAL GEOLOGY

The extensive pumice deposits in northern Klamath County, southern Deschutes County, and the northwest corner of Lake County are the result of violent eruptions about 5,000 years ago from now-inactive volcanoes. The volcanoes include the ancient volcano known as Mt. Mazama (Crater Lake now occupies a caldera in this partially destroyed mountain), Mount Newberry (Newberry Crater), and one or two smaller volcanic cones. The pumice on the Reservation was derived almost exclusively from Mt. Mt. Mazama. During the early stages of its eruption most of the ejecta consisted of small, gas-filled fragments of pumice, which were thrown high into the air and carried by the prevailing winds to the areas northeast, east, and southeast of the volcano. Later, less-explosive eruptions of glowing, gas-fluxed, flowlike avalanches, technically known as nuee ardentes, poured over the rim of the caldera and rushed down the flanks of the volcano into the valleys. Many of these flows coalesced to form the extensive pumice layer in the vicinity of Antelope Desert in the northeast corner of the Reservation and north of the Reservation near Beaver Marsh. In its waning stages of activity the volcano erupted a quantity of mafic scoria and cinders, which is intermixed with the upper pumice layers.

Two main types of pumice deposits resulted from these eruptions of Mt. Mazama; one derived from the settling of the fine pumice fragments that were carried by the wind, and the other from the glowing avalanches. Williams (1942) has classified the pumice deposits according to origin and has called them respectively "pumice fall" and "pumice flow". In this report the names proposed by Williams have been used, though the flow and fall deposits have also been called, respectively, lump pumice and granular pumice by Moore (1937). For a more detailed description of the origin and the geology of the pumice and related rocks of the area, the reader should refer to the reports listed above and to the report by Diller and Patton (1902).

The bedrock on which the pumice is deposited varies from place to place. In some spots the pumice overlies Pliocene lake beds which are partly diatomaceous. The lake beds are approximately horizontal and generally are exposed only in road cuts and in river banks. In other places the bedrock consists of Pliocene basalt and, locally, flows of olivine basalt which are probably Pleistocene or Recent in age. The basalts include those at Boundary Butte and other smaller cinder cones in the west-central part of the Reservation. The basalt flows are horizontal and crop out through the pumice as rim rock along valley walls. The pumice occurs as sheet-like masses; the pumice flow locally overlies the pumice fall. Both pumice layers are essentially horizontal, but vary in thickness over short distances owing to the irregular surface on which they rest and to erosion and drifting of loose pumice on the upper surface of the pumice layers.

DISTRIBUTION OF THE PUMICE

Most of the many hundreds of square miles that comprise the Klamath Indian Reservation are covered either by pumice fall or pumice flow material. (See pl. 1.) The pumice fall was carried by the wind for great distances from Mt. Mazama and immediately after eruption it covered not only the entire Reservation, but also many hundreds of square miles beyond the limits of the Reservation. The pumice flows, on the other hand, moved relatively short distances, and therefore are found only on the flanks of the volcanoes and in the adjacent valleys. On the Reservation they are confined to the area west of Klamath Marsh.

Approximate thicknesses of the pumice fall is indicated by isopachs on plate 1. In the area south of Chiloquin, along the Sprague River valley, and near Sycan Marsh and Yamsay Mountain the pumice fall deposits are generally less than a foot thick, and in parts of these areas the thin layer of pumice has been completely removed by erosion. The pumice fall deposits in the area immediately east and south of Klamath Marsh range from 5 to 20 feet in thickness, and a few drifts may be as much as 30 to 40 feet thick. The average thickness of the pumice in this area is perhaps as much as 15 feet.

Pumice flow deposits completely cover the area to the west of Klamath Marsh. Their maximum thickness as determined from well logs, ranges from 47 feet near Kirk to 90 feet in sec. 18, T. 29 S., R. 7 E., about 6 miles north of Lenz. In most places, however, these deposits contain numerous interbedded lenses and layers of red or black scoria, layers of sand derived exclusively from volcanic rocks, and layers of gray cinders. These are undesirable from the standpoint of commercial exploitation of the pumice. Neither the distribution nor the thickness of the layers of intermixed material can be predicted with accuracy.

RESERVES

Estimates of the total volume of pumice on the Klamath Reservation have varied, but they are alike in that they all are given in terms of billions of cubic yards. Probably about 1, 100 square miles of the Reservation are covered with 1/2 to 30 or 40 feet of pumice, and, locally, thicknesses up to 90 feet have been recorded. Assuming that the average thickness of the pumice is only 5 or 6 feet, which is believed to be a reasonable minimum figure, then the minimum total volume of pumice is about 6, 000, 000, 000 cubic yards. Most of this large volume is concentrated in the northwest corner of the Reservation, and for reasons given in a later part of this report much of it is not suitable or accessible for exploitation.

CHEMICAL COMPOSITION

Chemically the pumice of both the flow and the fall deposits is similar over the entire area and is of dacitic composition. The principal chemical constituents are silica, alumina, and soda. On the basis of chemical analyses listed in Moore (1937) and Williams (1942) a typical pumice sample contains about 69 percent SiO_2, about 15 percent Al_2O_3, slightly more than 2 percent combined Fe_2O_3 and FeO, about 2 percent CaO, less than 1 percent MnO and MgO, about 5 percent Na_2O, a little over 2 percent K_2O, and very small amounts of TiO_2, P_2O_5, plus approximately 3 percent H_2O. A quick determination of the chemical character of the pumice may be made by determining its index of refraction, and the indices of many samples from different parts of the Reservation were determined. The range of index of refraction in the samples tested was from 1. 500 to 1. 518. This indicates they are all of about the same dacitic composition.

PHYSICAL PROPERTIES

The textures of the pumice flow and fall deposits are distinct. The fall deposits consist of fine-grained, well-sorted, fragments of pumice; whereas the pumice flow is characterized by abundant pumice lumps of various sizes in an impure matrix of crushed and powdered dacite glass. Numerous mechanical analyses made by Moore (1937), Williams (1942), and others have exhibited these gross differences in texture, but minor textural differences are infinitely variable. The writer has selected a number of representative mechanical analyses and has included the data in tables 1 and 2.

PUMICE FALL

The fresh pumice fall material is white or light gray, but where weathered it is pale buff or brownish yellow. Little or no stratification is evident in these deposits; they are neither compacted nor cemented. The individual pumice grains are angular to subrounded and nearly equidimensional. They contain phenocrysts of feldspar, hornblende, hypersthene, augite, and magnetite. Commonly the material is well sorted; the grains range from 1. 2 to 2. 4 millimeters in diameter, though small amounts of both larger and smaller fragments have been found. The smaller fragments are usually mineral grains. A few fragments of foreign rock material are found in the fall deposits.

Air cells in the pumice are of nearly uniform size and are evenly distributed. As a result pumice fragments are fairly strong and resistant to crushing. One sample tested by the Bureau of Reclamation absorbed 40 percent its initial weight after being immersed in water for 5 minutes.

PUMICE FLOWS

The pumice flow material is pale gray to buff where fresh, but the weathered top 5 to 10 feet of these deposits is stained a pink or pinkish buff. The pumice debris in the flows is neither cemented nor highly compact and stratification is faint or absent. Poorly defined layers and lenses of scoria and cinders are interbedded with the pumice. The distribution of these layers is haphazard, and it is not possible to ascertain either

Table 1.—Mechanical analyses, in millimeters, of pumice (from Moore[1])

No. on pl. 1	Locality	64-32	32-16	16-8	8-4	4-2	2-1	1-0.5	0.5-0.25	0.25-0.125	Less than 0.125	Total
	Finer portions of flow material											
42	Northwest corner, SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 35, T. 31 S., R. 7 E..........	7.5	3.0	3.2	3.3	4.0	7.0	17.6	25.5	12.5	16.4	100.0
45	Center, SW$\frac{1}{4}$ sec. 32, T. 31 S., R. 7 E......................	--	5.6	5.9	5.8	6.3	8.2	14.3	20.5	11.6	21.8	100.0
46	South center, SE$\frac{1}{4}$ sec. 9, T. 31 S., R. 7 E..................	3.8	7.4	8.8	7.7	6.0	7.1	10.9	16.1	10.4	21.8	100.0
47	Southeast corner, sec. 27, T. 30 S., R. 7 E................	16.9	3.7	3.0	3.4	4.7	6.4	12.5	18.3	11.8	19.3	100.0
48	Extreme south center, NE$\frac{1}{4}$ sec. 14, T. 30 S., R. 7 E.........	4.3	11.5	8.4	5.9	5.8	7.8	13.4	15.7	8.5	18.7	100.0
54a	Northeast corner, sec. 1, T. 29 S., R. 7 E................	14.8	12.0	10.7	2.3	1.0	4.5	11.6	12.9	8.4	21.8	100.0
55	North center, SE$\frac{1}{4}$ sec. 31, T. 32 S., R. 8 E................	--	1.1	6.0	6.5	6.3	7.0	10.5	12.7	12.4	37.5	100.0
61	Southwest corner, NW$\frac{1}{4}$ sec. 12, T. 30 S., R. 8 E............	--	4.3	6.1	6.1	5.7	6.9	10.3	14.0	12.0	34.6	100.0
64	North center, NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 28, T. 29 S., R. 8 E.............	5.7	3.6	5.3	4.9	4.9	6.7	8.2	11.0	13.5	36.2	100.0
	Fall material											
40	Center, SE$\frac{1}{4}$ sec. 14, T. 32 S., R. 7$\frac{1}{2}$ E......................	--	4.4	15.5	32.4	27.5	13.5	4.9	1.0	.8	--	100.0
57	Northwest corner, sec. 33, T. 32 S., R. 8 E................	--	1.1	4.5	17.3	24.3	27.1	18.2	5.0	2.5	--	100.0
58	Southwest corner, sec. 32, T. 32 S., R. 8 E................	--	6.1	18.7	29.6	26.0	13.4	4.8	.9	.5	--	100.0
59	Center, N$\frac{1}{2}$ sec. 15, T. 31 S., R. 9 E.; upper part of sheet...	--	1.7	50.7	32.6	12.0	1.5	.5	.5	.5	--	100.0
60	Same as 59 but lower part of sheet.........................	--	.8	7.5	21.4	32.3	24.0	6.5	3.6	3.9	--	100.0
73	Southwest corner, NW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 7, T. 30 S., R. 10 E..........	--	4.9	17.2	30.4	28.0	12.3	3.3	2.1	1.5	--	100.0
74	SE$\frac{1}{4}$ sec. 25, T. 29 S., R. 9 E...............................	--	18.6	29.3	25.4	11.8	5.6	5.3	2.0	2.0	--	100.0
90	West center, SW$\frac{1}{4}$ sec. 5, T. 34 S., R. 7 E...................	--	--	.2	3.9	18.9	37.4	30.5	8.5	.6	--	100.0
91	Center, SW$\frac{1}{4}$ sec. 32, T. 33 S., R. 7 E......................	--	--	5.7	21.3	43.4	27.8	6.4	.2	.2	--	100.0
92	Center, E$\frac{1}{2}$SE$\frac{1}{4}$ sec. 34, T. 32 S., R. 9 E..................	--	2.8	11.4	28.3	27.2	18.1	9.8	2.0	.4	--	100.0
93	Southeast corner, SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 12, T. 33 S., R. 9 E.........	--	--	3.6	17.4	30.6	28.1	17.0	3.1	.2	--	100.0
94	Southeast corner, SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 35, T. 30 S., R. 9 E.........	--	1.7	11.3	23.6	28.9	17.6	13.8	2.9	.2	--	100.0
95	Southeast corner, sec. 25, T. 30 S., R. 9 E................	--	3.8	10.3	25.4	28.3	17.1	13.3	1.6	.2	--	100.0
96	NE$\frac{1}{4}$SW$\frac{1}{4}$ sec. 28, T. 30 S., R. 11 E.........................	--	--	1.9	16.6	27.1	22.8	22.7	8.2	.7	--	100.0
97	Southeast corner, SW$\frac{1}{4}$SW$\frac{1}{4}$ sec. 7, T. 33 S., R. 11 E.........	--	--	2.0	11.8	25.5	27.8	26.6	5.7	.6	--	100.0
98	SE$\frac{1}{4}$NW$\frac{1}{4}$ sec. 2, T. 33 S., R. 10 E.........................	--	--	1.9	11.9	23.8	26.9	26.7	8.3	.5	--	100.0
99	Center, NW$\frac{1}{4}$ sec. 31, T. 33 S., R. 10 E.....................	--	--	1.7	11.5	21.4	23.3	27.2	14.2	.7	--	100.0
100	Northeast corner, SE$\frac{1}{4}$ sec. 16, T. 34 S., R 9 E...............	--	--	1.2	12.4	27.4	31.6	18.3	8.8	.3	--	100.0

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[1] Moore, B. N., Nonmetallic mineral resources of eastern Oregon: U. S. Geol. Survey Bull. 875, 1937. Numbers refer to Moore's sample localities. Location of samples is shown on plate 1 of this report by an open circle.

Table 2.--Mechanical analyses, in inches, of pumice made by Bureau of Reclamation

Samples collected by G. W. Walker. Location of samples is shown on plate 1 by a circle containing a cross. Sample 56 is from pumice flow deposits. Sample 58 is from pumice fall deposits. Sample 59 is from pumice flow deposits but has been reworked by wind and water

No. on pl. 1	Locality	3-1.5	1.5-.75	.75-.375	.375-.187	.187-.094	.094-.047	.047-.023	.023-.012	.012-.006	Less than .006	Total
56	NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 24, T. 29 S., R. 7 E...........................	2.2	3.4	4.8	5.4	7.3	8.2	11.4	13.8	11.7	31.8	100.0
58	SW$\frac{1}{4}$ sec. 1, T. 33 S., R. 7 E................................	--	--	--	1.2	37.5	50.9	5.5	.5	.2	4.2	100.0
59	Same as 58; lies stratigraphically below...................	--	.5	1.9	3.3	5.0	7.1	10.0	13.6	14.6	44.0	100.0

their distribution or thickness from surface evidence. The scoria and cinders are gray, black, or red and consist of highly vesicular brown or gray glass, which locally contains abundant phenocrysts. All samples of the scoria that were tested were basaltic in composition. Locally, the pumice flows contain some charcoal logs and fairly abundant extraneous flow rock fragments.

The pumice flows consist of lumps of pumice embedded in a matrix of finer material made up of both mineral grains and glass fragments. Mechanical analyses show a greater range in the size of the pumice-flow particles than in that of the pumice fall. A fairly large portion of grains and fragments in the matrix are less than 1 millimeter in diameter, whereas the lumps are large subrounded fragments that are as much as 1 foot or more in diameter. Locally, the matrix comprises 50 to 60 percent of the total material.

The pumice is highly vesicular and frequently very frothy and fibrous dacite glass, which nearly always contains moderately abundant phenocrysts and crystal fragments of plagioclase (oligoclase to labradorite), hornblende, quartz, hypersthene, biotite, and magnetite. Small amounts of opal have also been found as fragments in the matrix and, locally, the walls of some vesicles are thinly coated with opal. The vesicles have a great range in size and because of this the pumice commonly has little structural strength and can be readily crushed, differing in this respect from grains of pumice fall. Laboratory tests by the Bureau of Reclamation on lumps of pumice indicate a high degree of interconnection of voids. Some lumps absorbed as much as 1-1/2 times their initial weight of water during only 5 minutes immersion.

USES AND STANDARD REQUIREMENTS

The principal use of pumice is as a lightweight aggregate in concrete and acoustic plaster. Large quantities are also used as an abrasive in cleansing and scouring compounds, in finishing furniture and other wood products, and in finishing metal surfaces prior to silver-plating. Locally, large quantities of a select type of pumice also have been used as pozzuolana in the manufacture of pozzuolanic cement. Although pumice is also used in manufacturing insecticides, insulating material, filters, solvents, and plastics, and as paint filler, absorbent material, and chicken grits (U.S. Bur. Mines, 1948), the total amount so used is small. The only uses that have been considered in this report are as aggregate, pozzuolana, or abrasive, because in central Oregon the main markets available to pumice producers are for these three uses.

PUMICE FOR AGGREGATE

Ideally, pumice that is to be used for lightweight aggregates, should have adequate structural strength though light in weight, (U. S. Bur. Reclamation, 1949; Am. Soc. for Testing Materials, 1944). Void spaces should be fairly uniform in size and shape and should not be interconnected. The aggregate should be relatively inert and free from contaminating substances such as silt, clay, mica, coal, humus, and other organic matter, and chemical salts, and it should also have a low opal content. The best aggregate has a fairly even distribution in the size of particles which range from very fine sand to about one-fourth inch.

PUMICE FOR POZZUOLANA

Pumice that is to be used as pozzuolana, in contrast to pumice for aggregate, should in the presence of water react with the lime in cement to form compounds that have low solubilities and possess cementing properties. Materials with a high opal content are reactive and are, therefore, usually best suited for this purpose. Substances that occur naturally usually are too coarse to be used directly as pozzuolana without fine grinding to meet specifications.

PUMICE FOR ABRASIVE MATERIAL

High quality abrasives (Hatmaker, 1932; Am. Inst. Min. Met. Eng., 1949) derived from pumice requires material that is hard, sharp, and uniform in texture and particle size. The size and shape of the vesicles in the individual particles should also be uniform. The best abrasive material is in lumps 3 inches or more in diameter. Grains or crystals of feldspar, quartz, or other foreign minerals in pumice prohibit its use where high-grade material is needed. Lower quality abrasives may contain small amounts of deleterious, gritty, and noncellular material, and the texture and size of vesicles do not have to be uniform.

SUITABILITY FOR COMMON USES

Tests of the physical and chemical properties of pumice from the Klamath Reservation by the writer and by the Bureau of Reclamation laboratories, as well as data obtained from the reports by Moore (1937) and Williams (1942), indicate that the pumice is suitable, with some limitations, for use as an aggregate and as an abrasive. Only preliminary tests were made on the pumice for its suitability as a pozzuolanic material, because the cost of such testing is very high and not warranted until such time as a demand for large tonnages for pozzuolana can be foreseen.

In a report by R. H. Cook (1951) of the Bureau of Reclamation on the properties of three samples of the pumice for the Reservation, he states:

> "From a petrographic standpoint the pumice fragments constituting the three samples appear to have potential value for use as aggregate in lightweight concrete. However, samples No. 56 and 59 (Pumice flow material--see table 2) contain excessive amounts of fine material and sample No. 58 (Pumice fall material--see table 2) is deficient in several size fractions. Inasmuch as grading is a critical factor in producing a workable lightweight concrete, this poor graduation might impose economic restrictions on use of the material as aggregate because of the large volume of material which must be processed to produce an aggregate of proper grading.

> "Experience indicates that concrete made of excessively fine pumice is generally of poor quality and suited for only very limited use. Excessive absorption of pumice tends to reduce workability of concrete. Heat treatment of the pumice tends to overcome this difficulty, and in addition tends to increase the quality of concrete which can be made. The glass of which the pumice and fine ash are composed is a type known to be deleteriously reactive with high-alkali cement."

In the same report he also evaluates the pumice for its suitability for pozzuolana. His comments are as follows:

> "From a petrographic standpoint, the samples appear worthy of further testing for suitability as pozzolan, inasmuch as experience indicates that some dacite tuffs and ashes produce effective pozzolans. All these samples would require grinding to achieve the fineness necessary for pozzolanic materials, consequently, cost of processing may decide the feasibility of commercial exploitation. The rock and mineral particles present would tend to reduce the pozzolanic activity of the samples. However, it cannot be determined without further testing whether the amounts of these inactive constituents are so great as to render the material unusable."

Tests by the author show similar properties for a number of other samples of both the pumice fall and the pumice flow, though two samples from the pumice flow deposits were even more absorptive than those examined by the Bureau of Reclamation. The high degree of interconnection of voids (effective permeability) in the flow pumice reduces the thermal and acoustic insulating values of the pumice, and when used in concrete causes excessive absorption of water. This reduces the workability of the concrete.

Tests have shown that pumice in the fall deposits meets most requirements for use as a lightweight aggregate. Apparently it is sufficinetly inert, and material can be obtained that is pure and largely free of contaminating substances. Individual pumice fragments are light in weight, and have adequate structural strength. It is deficient in that the range in the size of particles is small, consisting almost entirely of coarse sand-sized grains. The pumice of the flow deposits is equally inert, and locally, pure and unadulterated pumice can be obtained. The material contains a wider distribution in the size of fragments than the pumice flow, but in most localities it contains too high a proportion of fine particles or too many large lumps to be used without processing. The large lumps of pumice are extremely frothy, a condition which decreases their strength and increases their absorptive characteristics. Nevertheless, the pumice fall material that has been tested is much the same as that being utilized for aggregate and plaster sand to the north of the Reservation. The deposits to the north, however, have a slight advantage in being better sorted and requiring less crushing and screening to meet the specifications of the consumers.

Tests of the pumice on the Reservation show that neither the flow nor fall pumice is suitable for high-quality abrasive, because it is uniform in neither texture nor vesicle size, and it has a fairly high content of phenocrysts and foreign mineral grains. A much lower grade abrasive can be obtained, however, by hand sorting lump pumice from the flow deposits, but at the present time there apparently is little demand for such material.

PUMICE PRODUCTION IN OREGON

In the past few years pumice production in the State of Oregon has been dominated by the various pumice producers in the Bend-Chemult area north of the Reservation. Most of the pumice has been sold to Oregon consumers, although small quantites have been sold outside the State, particularly to Washington and California producers of pumice blocks and acoustic plaster. The total production of the State in 1948 was 170, 500 cubic yards[1] valued at about $305, 000. This was an increase of about 40, 000 cubic yards over 1947 production. This material was used almost exclusively in making lightweight blocks and for acoustic plaster, though a very small quantity was shipped to eastern consumers for use as a low-grade abrasive. In 1949 production of pumice fell slightly to 169, 036 yards, owing in part to the increased use of haydite (thermally expanded clay or siltstone) and other expanded materials for lightweight aggregate. These synthetic lightweight materials usually have advantages over natural pumice, because their properties can be regulated to meet exacting specifications of grain size and porosity. Total production figures on pumice in Oregon for 1950 are not yet available but various pumice producers have reported that haydite production has again increased.

ECONOMIC VALUE

Large volumes of pumice flow and pumice fall material on the Klamath Indian Reservation are potentially available for commercial exploitation. Tests of the chemical and physical properties of the pumice indicate that it is suitable, with some limitations, for use as an aggregate and as an abrasive. Preliminary tests indicate that it may also be suited for use as pozzuolana. Many factors, however, must be considered by prospective pumice producers.

The location of potential sites for pumice pits must be near available lines of transportation. In this respect, the pumice deposits in the northwest part of the Reservation are well situated, as subsidiary branch lines of the Southern Pacific Line and Great Northern Railway traverse this area. It is also served by U. S. Highway No. 97.

The thickness of the deposits must be considered in evaluating the pumice and in locating

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[1] Production figures published by Oregon State Department of Geology and Mineral Industries.

possible future pumice pits. Past experience in developing central Oregon pumice has shown that the top 2 to 4 feet of pumice must be discarded, because of the deleterious effect of contained soil and plant material. Experience has also shown that an adequate working face in pits must be maintained for low cost production; usually this working face needs to be 8 feet or more. The pumice, therefore, must be at least 10 or 12 feet thick, to be worked economically. Areas adjoining Klamath Marsh are underlain by pumice layers that are consistently 10 feet or more in thickness.

The most favorable sites for the development of the pumice are in the northwest corner of the Reservation in Tps. 29 and 30 S., Rs. 7 and 8 E. The deposits in this area consist of pumice flow, with some local layers of scoria. They are best suited for exploitation because they are thick and widespread and are readily accessible to transportation. Chemically they are acceptable for aggregate and possibly for pozzuolana. In its natural state, however, the material is poorly sorted and the individual pumice lumps are highly absorptive and have little structural strength. These difficulties can be overcome, at least in part, by screening and processing.

To obtain a higher grade lightweight aggregate, fall pumice material could be mixed with the processed flow pumice, as an aggregate better sorted in size is formed by mixing the two types. The grains of pumice fall also would add to the strength and insulating qualities of the aggregate. Probably the most favorable place to develop the pumice fall deposits from an economic standpoint is in the southern part of T. 32 S., R. 8 E., but more detailed testing of the thickness of the deposits in this area would be necessary before quarry sites could be definitely located.

Lump pumice that can be used for a low-grade abrasive occurs only in the flow deposits. It must, therefore, be obtained from the northwest corner of the Reservation, but even in this area the distribution of lumps suitable for abrasive is so erratic that it is not possible to specify any localities that are particularly favorable for development.

The tremendous volume and adequate grade of pumice on the Reservation do not in any way guarantee that a new pumice operation can succeed. In recent years most of the pumice produced from central Oregon was used for lightweight aggregate, but the quantity used decreased during 1949 and early 1950, owing in part to wider use of haydite and other synthetic lightweight aggregates. Competition for this shrinking market is keen, and prospective pumice producers should have assurance of adequate and secure markets before making large expenditures for detailed exploration or equipment.

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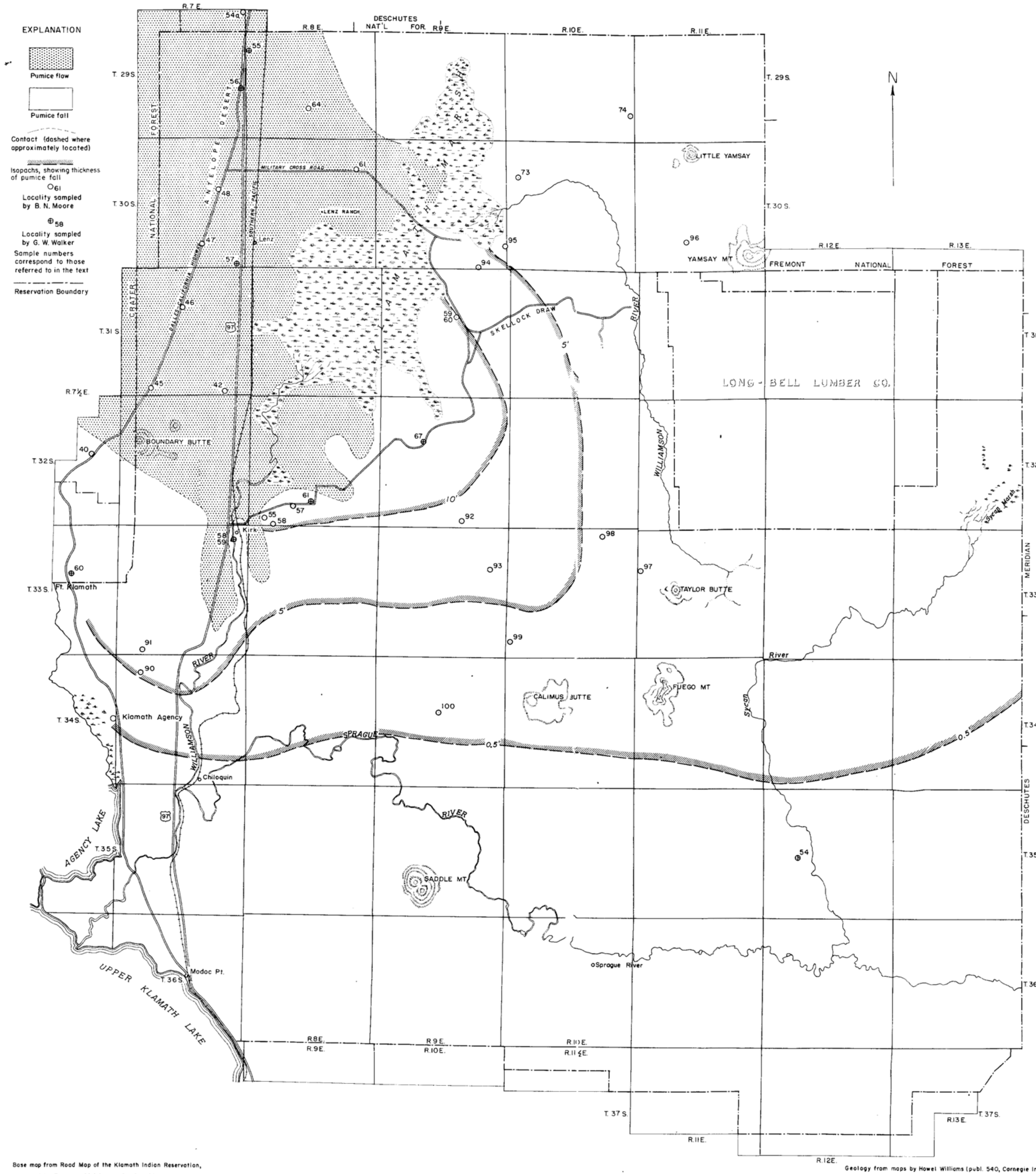

Base map from Road Map of the Klamath Indian Reservation, prepared by Forestry Division, U. S. I. S., 1932

Geology from maps by Howel Williams (publ. 540, Carnegie Inst. of Washington, 1942) modified by G. W. Walker, December 1950

MAP SHOWING DISTRIBUTION AND THICKNESS OF PUMICE ON THE KLAMATH INDIAN RESERVATION, KLAMATH COUNTY, OREGON

1 0 5 Miles