

VOLUME I

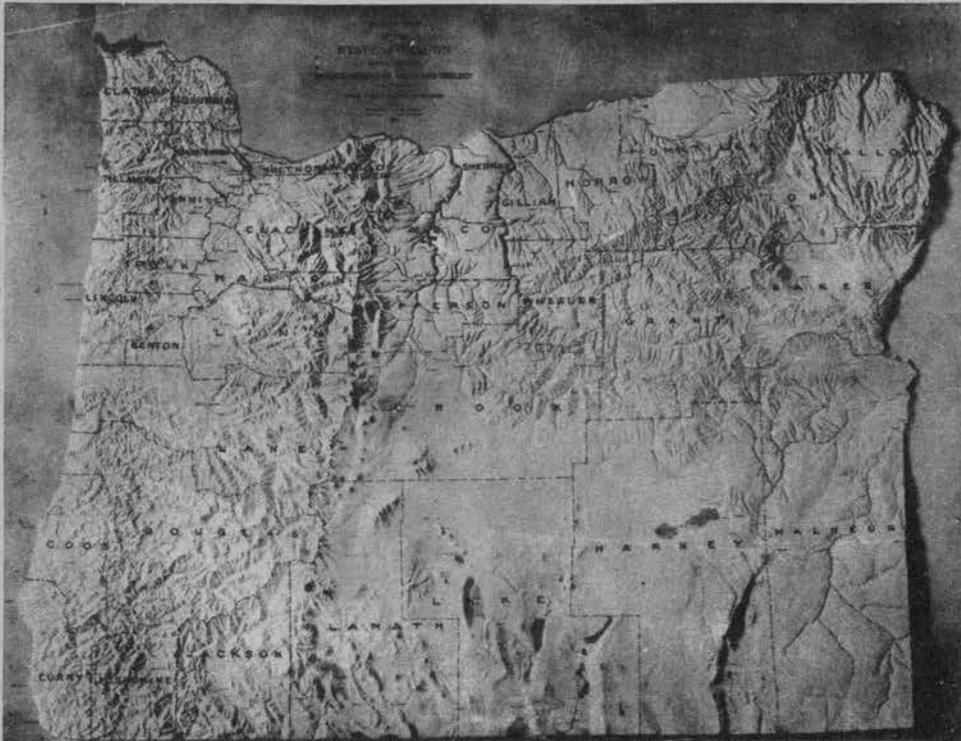
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NUMBER 7

NOVEMBER, 1914

THE MINERAL RESOURCES OF OREGON

Published Monthly By
The Oregon Bureau of Mines and Geology



The Relief Map of Oregon

Construction and Use of the Relief Map

By S. SHEDD

Tests of Building Brick, Hollow Blocks, and Drain Tile

By IRA A. WILLIAMS

Limestone Deposits in Oregon

By IRA A. WILLIAMS

Entered as second class matter at Corvallis, Ore. on Feb. 10, 1914, according to the Act of Aug. 24, 1912.

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Volume I

Number 7

November Issue

of the

MINERAL RESOURCES OF OREGON

Published by

The Oregon Bureau of Mines and Geology



CONTAINING

Construction of the New Relief Map of Oregon

Tests of Brick, Blocks and Drain Tile

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1914

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RELIEF MAP
OF THE
STATE OF OREGON
MADE BY THE
OREGON BUREAU OF MINES AND GEOLOGY
UNDER THE SUPERVISION OF A. W. HEDD
1914



Fig. 1. The Relief Map of Oregon.

VOLUME I

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THE MINERAL RESOURCES OF OREGON

*A Periodical Devoted to the Development
of all her Minerals*

PUBLISHED MONTHLY AT CORVALLIS BY
THE OREGON BUREAU OF MINES AND GEOLOGY
H. M. PARKS, Director

A NEW RELIEF MAP OF OREGON

A relief map of Oregon has just been completed by the Oregon Bureau of Mines and Geology. This map is on the large horizontal scale of 4 miles to the inch, while the elevations and depressions are shown on a scale of 4,000 feet to the inch. The completed map is about 8 by 10 feet.

This map is an actual representation of Oregon as a small portion of the earth's surface, and shows mountains, valleys, streams, and all other natural features just as they exist. Upon it are placed the railroads, cities, highways, and other man-made improvements, so that one has laid out before him, not a mere picture or drawing, but a reproduction of Oregon herself, so that every part may be seen at a glance.

Each map is attractively mounted and framed so that it is suitable for installation and use for any desired purpose.

Dr. Solon Shedd, professor of Geology in Washington State College, did the necessary field work and constructed the original map, or positive, for the Bureau of Mines and Geology. A negative has been cast in plaster from this original and from this negative as many duplicate maps may be made as are needed. The cost of a completed map, showing county boundaries, rivers, railroads, principal cities and towns, chief mountain peaks, lakes, and any

other matter that may be put on the map to adapt it to any particular purpose, will be near 100 dollars.

Professor Shedd has prepared the following brief statement of the method of constructing the map and of the important uses which it may serve. A photograph of a finished map is reproduced in fig. 1.

THE CONSTRUCTION AND USE OF THE RELIEF MAP

BY S. SHEDD

The practical use to which topographic models or relief maps have been put has so widened in the last few years that they are rapidly coming into favor for other than purely scientific purposes. The value of maps of this kind is also being more appreciated for illustrations and instruction.

Ordinary topographic maps representing by contour lines the elevations and depressions of the earth's surface, are now demanded in engineering work of practically every description. Maps of this character afford a ready means of bringing out the configuration of the country in a simple manner. Splendid maps of this kind are made by the U. S. Geological Survey and by some of the state geological surveys. Persons not skilled in the interpretation of contour maps are not able many times, however, to understand them, and it may then be necessary to represent the same area in relief with the rivers, railroads, etc., shown upon a model.

Various methods are used in the construction of relief maps, but the one followed by the writer has given very satisfactory results as regards both accuracy and ease of manipulation. It consists in cutting out the contours, which have been reduced to a uniform scale from available maps and field data, in cardboard of the proper thickness to represent the vertical interval selected, building up and finishing in wax.

In the construction of a relief map the first thing to be determined is the scale on which the area will be represented. Several things have to be considered in determining this point, among which are the purposes for which the map is intended, amount of data obtainable, topography of the area to be modeled, as well as the amount of time and money available for doing the work.

In case the model is to be worked out in minute detail and used for practical purposes, the scale should be much larger than would

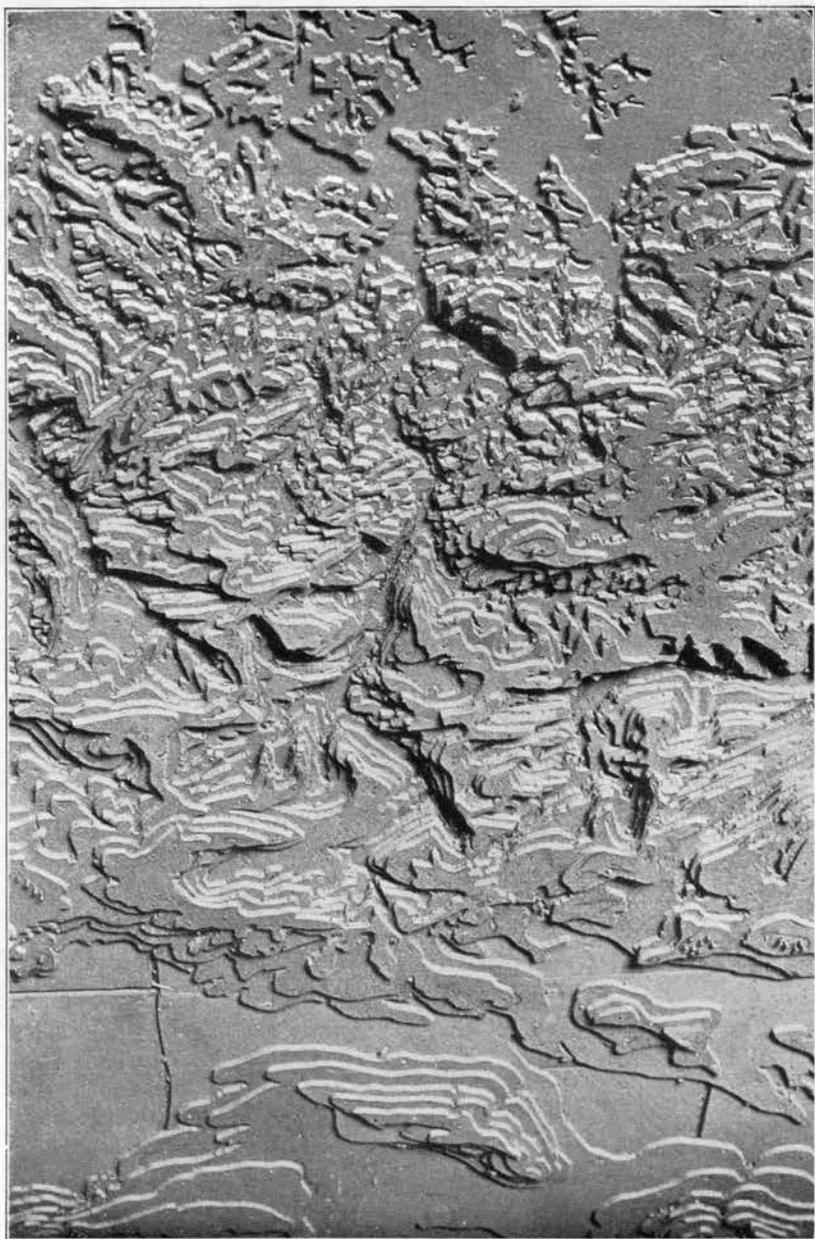


Fig. 2. Showing how a relief model is built up in its first stage, by nailing one on top of another, the successive contours cut from cardboard. In the lower and in the extreme upper parts of the view, the topography is comparatively mild; while the irregular shapes and greater number of layers in the middle portion of the photograph indicate a region of intricate topographic features.

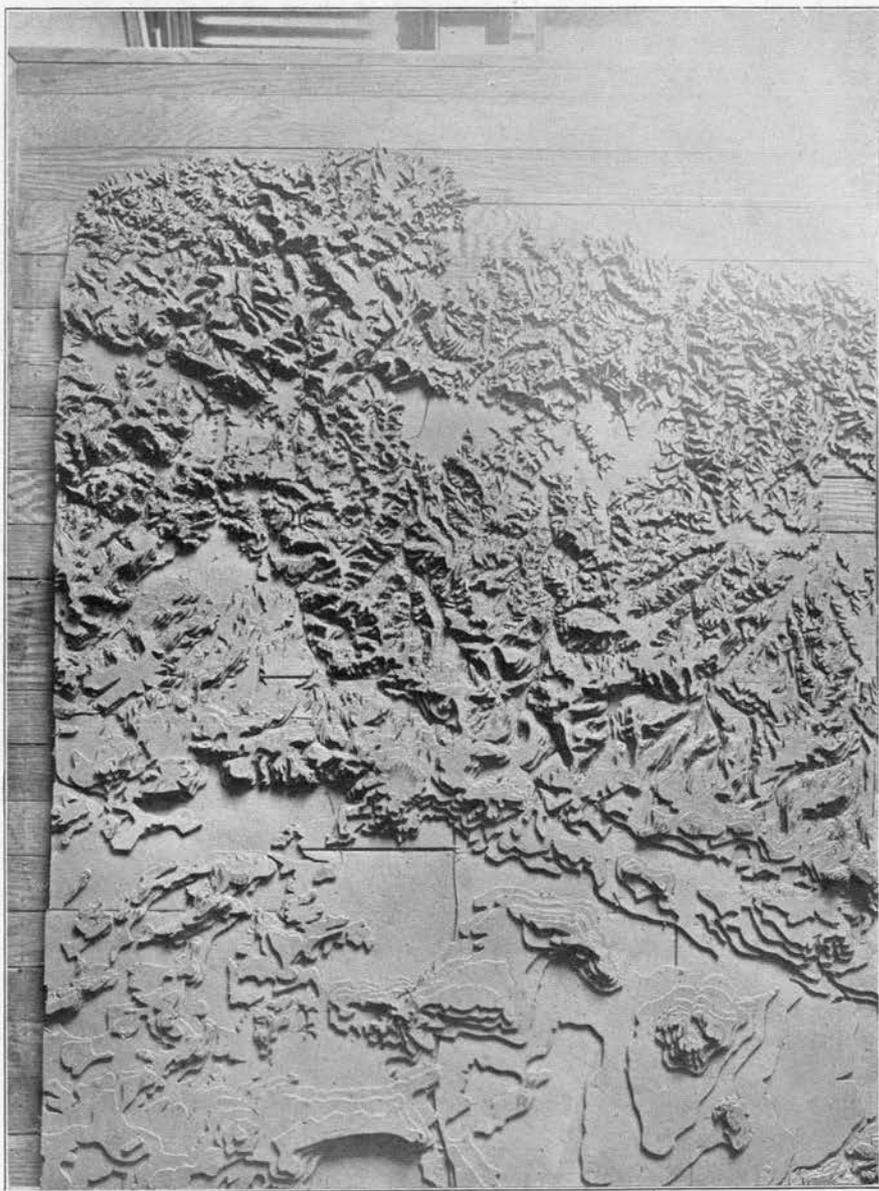


Fig. 3. One quarter of the relief map of Oregon in the first stage of the process of making. The cardboard contours over which the wax is to be modeled are all fastened in their proper positions. This view shows also, to some extent, the way in which the wooden base is built.

be necessary if it were intended to give only a very general idea of the country modeled. After the horizontal scale has been determined the next step is to procure a good contour map of the area to be modeled. If such a map can not be had, one must be made and from it must be decided what shall be the ratio between the horizontal and vertical scales. The aim should be to have this relation such that the slopes will look natural. Before deciding on the vertical scale, sections should be constructed at different places across the map. Various vertical scales should be used in these cross-sections, the sections then studied carefully, and the scale adopted that makes the most natural appearance.

Persons attempting the work of relief map making should have a thorough knowledge of how topographic maps are made, and of office practice, as well as possess skill in the use of tools and in the manipulation of materials. A thorough knowledge of topographic forms is also needed such as can be obtained only by a very careful study of the features of actual land surfaces of many types.

When the scale of the map has been determined, a good strong base on which to build it must be provided. This should be made of good lumber that has been thoroughly seasoned so it will have the least tendency to warp and crack. A very good way to construct this base is to use four thicknesses of half-inch lumber. Two thick-

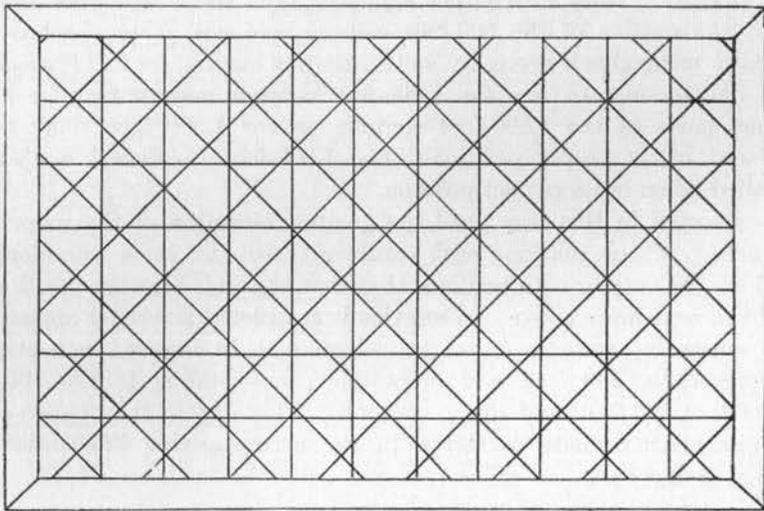


Fig. 4. Diagram showing how the base for the relief map is built; made of four thicknesses of half-inch lumber so as to prevent warping. Not drawn to scale.

nesses of the lumber should extend diagonally across the base in opposite directions; the other two, one above and the other below the diagonal ones, should be placed in such a way that they will cross the base in opposite directions and at right angles to each other. Surrounding these should be a border made of one by two-inch lumber on edge and firmly fastened to the base. A strong border of this kind will greatly assist in preventing the base from warping. The illustration (fig. 4) shows the manner of constructing this base.

The baseboard having been prepared, the outline of the map and the first contour should be transferred to it. This may be done by placing carbon paper on the base, laying the map over this, and then tracing with a stylus the lines to be transferred. The contours are transferred to the cardboards in the same manner. The thickness of the cardboard to be used in building up the map is determined by the vertical scale of the map and the distance between the contours. Suppose the vertical scale of the model to be constructed is 4,000 feet to the inch, as was used in making the Oregon map, and that the contour interval is 500 feet. In this case there would be as many cardboards to the inch as 500 is contained times in 4,000, or 8. Each cardboard should then be just one-eighth of an inch thick. Transfer both the 500 and the 1,000-foot contours to the cardboard. Then with either a jig-saw or a small band-saw first cut the outline of the 500-foot contour and nail it to the baseboard using glue if necessary, in the position marked for it. Proceed in like manner to saw the 1,000-foot contour and to transfer at least parts of the 1,500-foot contour, so the 1,500 layer may be placed in its proper position. The 1,000-foot cardboard is then nailed down in its correct position.

Proceed in this way until the greatest elevation of the map is reached, always marking each cardboard with two lines, one along which the cutting is to be done, the other as a guide for the position of the next layer above. When this is completed the relief appears in successive terraces one-eighth of an inch in height, each step representing 500 feet, and in outline corresponding to the 500-, 1,000-, 1,500-foot, and so on, contours. This step in the process of making such a model is shown in the accompanying illustrations (figs. 2 and 3).



Fig. 5. A close view of a portion of the unfinished relief map, showing below the uncovered cardboard contours, and above an area in which the cardboard is being covered with the modeling wax to reproduce the exact surface features.



Fig. 6. One quarter of the relief map of Oregon completed in wax modeled over the cardboard contours. It is from this original model that a negative is cast in plaster from which as many duplicates of the original may be made as desired.

The model is now ready to have the topography worked over the cardboard. For this purpose the following preparation is used.

Beeswax.....	16 parts
Venice turpentine.....	4 parts
Corn starch.....	8 parts
Venetian red.....	1 part
Sweet oil.....	1 part

Melt the beeswax, add the Venice turpentine, sift in the corn starch, stirring the mixture thoroughly during the addition of the starch, after which the Venetian red or other coloring matter, together with the sweet oil, may be added.

The different ingredients in the above mixture are inclined to separate somewhat, and, on account of this, the mixture should be stirred until it is almost cold or at least until it begins to thicken. As soon as the mixture is cold it is ready to use. The wax should be of a consistency to work easily and this can be obtained by regulating the amount of sweet oil in the above formula. Very little heat softens this wax, the heat of the hand being sufficient to make it very pliable.

At this point the skill and knowledge of the topographer come into play in bringing out the finer details of the topography from the contour map between the successive steps formed by the cardboard. It is here that the mere mechanic may fail completely. One is here again strongly reminded that in order to model well he should have a thorough knowledge of topography obtained from a study of topographic forms in the field. This, along with mechanical ability and a high degree of patience, are requisites for good relief map making.

The tools employed may be made of hard wood, bone, or iron, and may be of various rounded forms and sizes, depending much on the character of the topography to be molded and, therefore, on the intricacies of the various shapes that are to appear on the finished model. In giving the final touches to the wax a little sweet oil used on the tools will be found very helpful (see figs. 5 and 6).

The original wax map may be finished in any suitable way and itself used if so desired, as the above wax is very durable and will last for a long time. Usually, however, the wax relief is employed only as a model from which to cast in plaster a negative or mold. This may be done by first giving the wax map a coat of shellac, and when this has had time to harden, applying a coating of oil

over the shellac to prevent the plaster from sticking to the map. Enclose the oiled map in a wooden frame and place on a flat surface to secure an even distribution of the liquid plaster when it is poured over it.

The correct amount of water should be put into a suitable vessel and into this plaster of Paris of good quality is sifted, and the whole stirred rapidly to prevent the formation of lumps and air bubbles in the mixture. Plaster is added until the mixture has about the consistency of cream, when it should be poured over the oiled map. It is then allowed to stand until the plaster is partially set or hardened, when the whole may be turned over and the wax model separated from the cast. The mold should be retouched and all imperfections corrected, allowed to dry thoroughly, after which it may be given a coat of shellac and is then ready to use. If time is an important element, the mold may be used before it is thoroughly dry.

Positives, or duplicates of the original wax-cardboard model, can now be made by casting from this negative mold. To make a positive the mold is oiled and plaster mixed and poured into it, proceeding precisely as was done in making the negative. Large casts may be strengthened in various ways, such as putting iron rods, wire netting or hemp in the plaster. Thick casts may also be hollowed out somewhat on the under side and made lighter in weight. Mixtures of various kinds other than plaster are also used to lighten large casts.

The finish of the model depends entirely on the purpose for which it is intended. It may be painted any color desired and the surface features, such as streams, towns, roads, railroads, etc., put on the painted surface either with paint or India ink. The finishing of the map is a very important matter and one that should be done by a skilled draughtsman. Unskilled work in drawing and lettering may ruin the appearance of an otherwise good map.

In the case of very large maps it is necessary to make them in sections so they may be handled more easily and safely. The Oregon map was constructed in four sections, the sections being worked together so they would fit perfectly.

USES OF RELIEF MAPS

Relief maps or models are useful in many ways, the following being some of the most important.

In the teaching of physiography they bring out in a way that

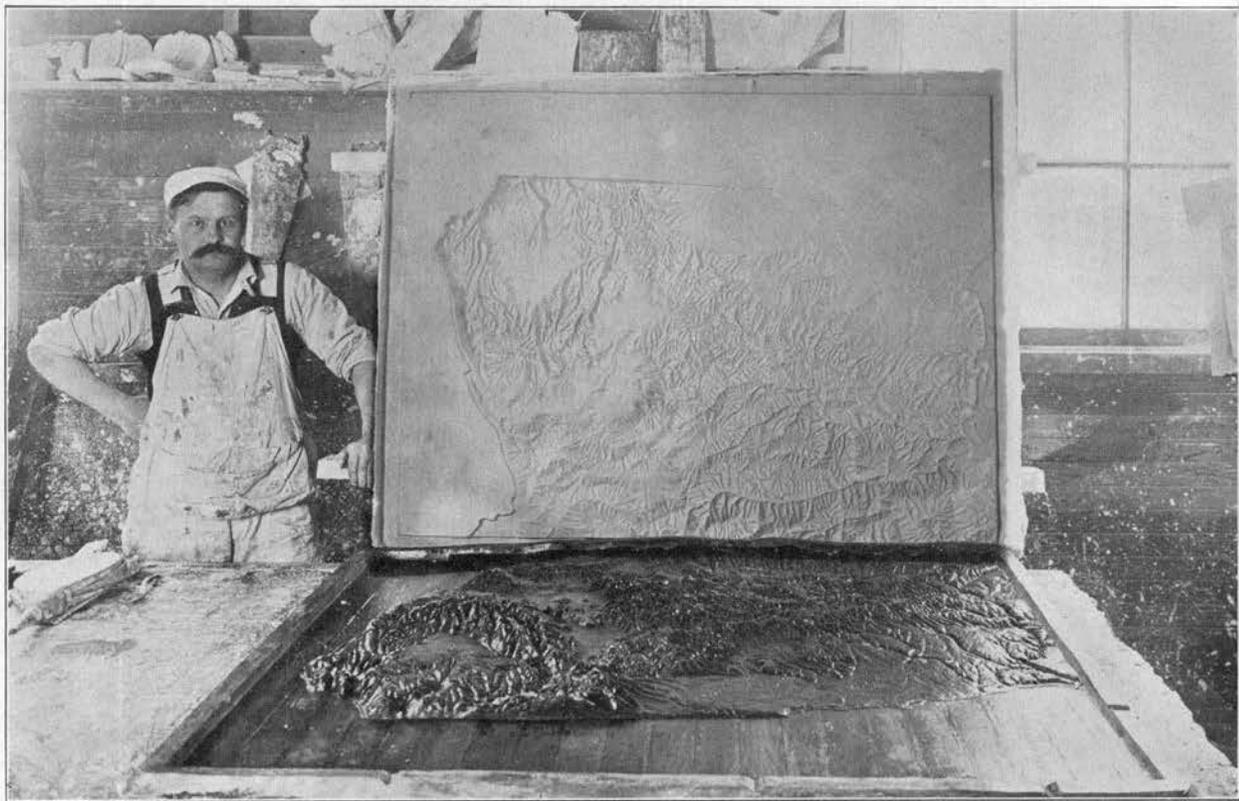


Fig. 7. Making the "plaster" negative of one-fourth of the Oregon relief map from the original wax model. The model is seen lying flat, while the cast, which has just been lifted from it, is standing vertically.

nothing else can the surface features of a locality. They show the relation of the mountains to the valleys and plains, the relative altitude above sea level of each of these, and their relative areas. They are especially helpful in explaining the cause of the climate of various localities, why in some places a large amount of precipitation occurs, and in others very little, why we have extremes of heat and cold in certain regions and an even temperature in others.

Models may also be of very great value in the teaching of geology in its various phases. This is especially true in regard to structural geology as the student in this way can have before him, in miniature, a representation of the rocks as he would see them in place in the field. Models of this kind may be very useful in the study of problems connected with forestry, agriculture, horticulture, grazing and many others of related character. For all of these purposes and in order to present to the young people of the state an exact conception of its many and varied surface features, and their practical bearings and meaning, one of the Oregon relief maps should be put into each high school of the state and used for reference in all economic studies relating to the state.

A relief map is very helpful in working out the geology of a region. When the nature and position of the rock strata are represented on a map of this kind, their relation to the topography is much better understood. The geology has much to do with determining the topography, and when these are both represented on a single model, it will be found of great value bringing, as it does, all of the facts in their proper relationship at once under the eye.

Instances are known where topographic models of this type have been of great assistance in cases of litigation. By the use of such a model a jury can very often obtain a truer conception of the actual position of a vein or its extent, the exact slopes or character of an area, or of other features in dispute, than they could by actually seeing them in the field.

In solving many of the every day development problems the relief map may be made an indispensable aid. Presenting accurately in one view, as it does, the actual features of Oregon's land surface on a large scale, a study of it will be an essential preliminary and accompaniment to the laying out of highway systems, to the location and development of water power and irrigation projects, in preliminary surveys for railroads, and in other enterprises in which a knowledge of distance, relief and grade is prerequisite.

No other means is so well adapted to exhibiting the resources of the state as is the relief map. Agricultural valley lands, foothill belts, rugged mountain slopes, forested and barren areas, may all be picturesquely yet accurately indicated. The position of lands in cultivation, fertile lands that are unsettled, mining regions, national parks and a multitude of other details of economic importance, may be accurately shown on the map in their correct relationship to public highways, railroads, streams, cities, etc. The relief map provides an eminently more suitable means than has before been available of showing to our own citizens, and to the vast number of inquirers who may become residents of Oregon, the character of the state and what its developed as well as its potential resources are.

**TESTS OF CLAY BUILDING BRICK AND HOLLOW
BLOCKS AND OF CLAY AND CONCRETE DRAIN
TILE MADE IN OREGON**

BY IRA A. WILLIAMS.

BUILDING BRICK TESTS

The use of brick for building purposes has been practiced since the very earliest times. The discovery that most common types of soils, and of clays, would make serviceable building materials when shaped and burned, has been the means of supplying to many isolated portions of all countries the essentials of home construction, therefore the beginnings of settlement. To the occupancy and development of regions where fuel is scarce and rainfall light, even the sun-dried adobe brick has very largely contributed. In brief, no other material of construction has been so universally used or a more important factor in the early growth of all countries of the world than the common clay building brick.

Although thus a world-old product, and although made from raw materials of varying character widely distributed over the earth, doubtless the common brick was used for ages before any attempt was made to determine, in any concrete manner, to just what properties its usefulness and permanence were due. It must of course be strong in order to be safely handled and to bear weight in use. In moist climates brick must be sufficiently close-textured

that the amount of water absorbed will not be too great. These facts were certainly appreciated by even the earliest users of brick. But the extent to which these same qualities may vary, or what their permissible limits are, were knowledge unknown to them. Indeed, until within a comparatively few years of the present time no systematic efforts were made to ascertain the essential qualities of building brick or to devise accurate methods of testing them.

It is possibly due to just such general use and acceptance of brick for all kinds of constructional purposes in all lands, and to the more or less universal impression that "a brick is a brick" that the development of methods of determining their properties has been so delayed. That there are good, poor and indifferent brick made and put upon the market is now thoroughly recognized. That brick may be entirely suited for one purpose or locality yet quite worthless for another is also a fact scarcely worthy of statement. The more recently developed processes of manufacture have likewise enabled brick manufacture to make a large variety of product differing widely in their individual qualities and therefore suited to widely different uses. It is these facts and the more and more keen competition that clay brick have had to meet in other building materials that have brought builders, architects and engineers face to face with the necessity of devising and applying a series of tests to building brick that will enable them to distinguish between good and poor, between acceptable brick and those unsafe for use in a given piece of construction.

From the standpoint of the manufacturer also a knowledge of the quality of his output, expressed in terms of the results of definite tests, is becoming increasingly important. When brick are to be offered for use on any contract it is highly advantageous for the manufacturer to be able to submit with his sample figures showing the approximate strength and other qualities of the brick he can furnish. The possession by the brickmaker of accurate data on the character of his product enables him to compare with those of like kind, and should be the basis on which he can determine for just what purposes his brick are suited. Expense and time may thus be saved to him which might otherwise be uselessly spent in urging the use of his goods under conditions where the tests show almost, or with entire certainty, they would prove unsatisfactory. The results of careful tests indicate to the maker of building brick also, as they do the maker of any other class of goods, wherein his

product falls short of the best and can frequently be made the basis or hint towards simple changes in the processes of manufacture that will bring about much to be desired improvement in the quality of his wares. The usefulness and need to both maker and user, therefore, of the adoption and carrying out of a set of uniform tests of the essential qualities of all brick regularly put upon the market are emphatically apparent.

The American Society for Testing Materials is an organization formed for the purpose of acquiring information concerning all materials of construction and to standardize the apparatus for and kinds of tests to be applied to all such materials. It is a notable fact that during the almost 20 years of the existence of the parent society (The International Association for Testing Materials), with which the American Society is directly affiliated, a constructive material so universally employed as are building brick, has received so little attention. For the past five or six years, however, a committee of the American Society has been at work on a set of standard specifications for brick tests. It will be appreciated at once that in order to determine first of all what tests should be made, and, secondly, to devise suitable equipment for making them, a large amount of experimental investigation would be necessary. This committee now has such preliminary work under way and has from time to time reported to its society the progress made.

A study of the conditions which structural brick must meet, used in the many ways that they are, has emphasized the importance of determining experimentally their ability to resist, (a) cracking when subjected to uneven strains, (b) crushing when heavy weight is put upon them, (c) entrance of water into their pores, and (d) disintegrating effects of freezing and thawing when saturated with water. The tests applied to ascertain these factors are now commonly referred to as, first, the cross-breaking or transverse test, second, the crushing test, third, the absorption tests, and fourth, the freezing and thawing test.

The work of the committee above referred to has progressed sufficiently that it now proposes that the four tests mentioned be recognized as the *standard* tests to be applied to building brick. The methods of carrying them out have been carefully considered and on the basis of the test data accumulated to date a proposed or tentative standard specification was presented to the American Society for Testing Materials in 1913 for adoption.

The testing of Oregon brick by the Oregon Bureau of Mines and Geology has been done in general along the lines of the methods proposed by the committee of the American Society. Brief consideration of the different tests made will therefore be given, followed by a statement of the results on Oregon brick and brief discussion of them.

SECURING THE BRICK SAMPLES

The sample brick for these tests, also the drain tile and building blocks for tests described on later pages, were for the most part selected at the various plants by the writer or other agent of the Bureau. Those not personally collected were sent in by the manufacturers according to the writer's explicit directions. In all instances an effort was made to obtain average brick that would be representative of the output of the individual plants. Since a chief object of the tests is to secure data that the brickmaker himself can use in selling his brick, particularly when offered in contractual competition, it was especially necessary always that the samples selected should be of such average quality as the manufacturer could supply in any quantity. Throughout the work the needs of the makers and of the users of brick have been kept primarily in mind, and in the treatise that follows an attempt is likewise made to so present the results that their maximum usefulness will be available to both.

CROSS-BREAKING TEST

For the transverse or cross-breaking test five average brick were used. Each brick was laid flatwise on two rounded knife edges with a span of seven inches, as shown in figure 10. The breaking load was applied from above, midway between the two supports, in a 50,000 pound Riehlé testing machine. Pressure was applied until the brick cracked, at which point the number of pounds was carefully read from the beam of the machine.

The strength of a brick when tested in this manner depends upon its cross section, that is, its thickness and width, and upon the distance between the supports on which it is placed. The closer the supports and the thicker the brick, the greater its breaking strength will be. In order to eliminate this one of the variable factors, the proposed standard specification recommends that in all brick tests the uniform distance of seven inches between supports

be employed, and this was used in the Oregon tests. Since two different brick are rarely of exactly the same cross section and, among different makes of brick no two are even identical in size, it is necessary in order to reduce the results of transverse tests to a uniform unit for comparison, to employ a formula which takes into account these variations in dimensions. What is called the *modulus of rupture* is obtained by using the expression

$$R = \frac{3w1}{2bd^2}$$

In this formula, R stands for the value sought, the *modulus of rupture*; w is the breaking *weight* applied in pounds; 1 is the *length* of span or distance between supports in inches; b is the *breadth* of the brick, and d its *depth* or thickness, all measurements being in inches.

The result to be obtained by the use of this formula necessitates careful measurement of the brick before breaking and gives the modulus in pounds per square inch of its cross section. In this form the values for different brick are directly comparable.

The practical purpose of the transverse test is to secure an idea of the ability of the brick, when laid in the wall, to withstand any variable strains or uneven pressures upon separate parts of it. Such strains may and frequently do come about by the settling of parts of the foundation and by the giving way of window and door arches or lintels. The unsightly rambling cracks thus produced are not an uncommon feature in brick walls almost everywhere. The natural tendency of the cracks is to follow the joints, if ordinary mortar has been used, and the smaller the number of brick broken through the less conspicuous is the defect. It is apparent that the real remedy for this trouble is the avoidance, in the construction of foundation and arches, of differential settle in any part of the wall. On the other hand, it is also evident that when such strains are brought to bear, the brick having the highest modulus of rupture, that is, the greatest resistance to cross breaking forces, will be least apt to crack in the wall.

A transverse test serves to indicate also the character of the structure of the brick. Brick made by the soft-mud process and by the dry-press method possess as a rule, a somewhat different texture, as well as structure, than do the auger machine made brick. This test will disclose any lack of uniformity in the clay body, as the enclosure of unground lumps of clay or of pebbles, or the presence

of excessive laminations in the auger-made product, all elements of weakness due to the methods used in making the brick. In general, the more uniform the structure in all parts of each individual brick and the harder burned they are, the higher will the transverse test show the modulus of rupture to be.

CRUSHING OR COMPRESSION TEST

Since it is known that the presence of a maximum amount of water in the brick usually affects its resistance to crushing, it was decided to carry out the compression test on both dry and saturated samples. For this test the halves of the brick broken in the transverse test were used, one-half of each being crushed dry and the other half wet. Five pieces were thus provided in each case from which to obtain an average result, a total of ten half-bricks, therefore, from each manufacturer.

Before making even the cross-breaking test, the bricks were dried to constant weight in a suitable oven at somewhat above boiling temperature. For crushing, the halves to be broken were accurately weighed and, after immersion in water, were boiled continuously for 4 hours. Experience has shown that active boiling for a few hours will very materially aid in completely saturating the brick, in which condition the pores are in large part filled with water. Before the pieces were crushed, both the wet and the dry samples were carefully measured and both the upper and lower bearing surfaces of each were coated with a thin layer of plaster of Paris. The faces of brick are rarely perfectly smooth or plane surfaces. Bedding in plaster is therefore necessary in order to secure an even distribution of pressure between the two heavy plain steel plates of the testing machine in which the brick were crushed.

A half-brick bedded and in position for testing is shown in figure 11. The pressure at which the brick fails is shown on the graduated beam, and this value divided by the number of square inches in compression, that is, the measured flat surface of the half-brick, gives the crushing strength in pounds per square inch. For example, suppose the crushing piece has a surface of 15 square inches and fails at 60,000 pounds. Obviously the ultimate strength per square inch is 60,000 divided by 15, or 4,000 pounds. In this manner a figure is arrived at for each test piece that can be directly compared with the results of others tested in the same way.

In the crushing or compression test, it is found that different

makes of building brick, and particularly brick made by different processes, behave differently. Some fail suddenly as though brittle, others relieve themselves slowly by crumbling or spalling and splintering at the edges, while still others tend to separate in concentric shells or layers before they finally collapse. The latter condition is noticed only in the case of some machine-made stiff-mud brick in which the action of the auger has produced laminations in certain definite directions, which are sometimes lines of weakness. Unless developed to an unusual degree, however, laminations are not to be considered a defect in building brick, since auger machine brick are very frequently more resistant in every way than the soft-mud product.

Whatever the manner or peculiarity of the brick in crushing, valuable clues may frequently be gained by observing the way in which they fail, as to not only the character of the raw materials used in their manufacture, but also whether these materials have been properly prepared and otherwise correctly handled in the manufacturing process. In other words, to one who is familiar in general with both methods of manufacture and the essential properties of building materials, the manner in which a brick crushes may be an important guide to improving the way the brick are made in often simple, sometimes radical ways, so as to correct defects or greatly improve the quality of the brick produced. In the writer's opinion the practical value of this test is as great from this standpoint, or greater, than from learning that a certain definite number of pounds of pressure is required to crush the brick.

In general it may be said that all masonry materials of accepted average quality are sufficiently strong to bear far more weight than ever comes upon them in use. To illustrate, the average weight of a number of Oregon soft-mud brick is about $4\frac{1}{2}$ pounds apiece, and we may assume for the purpose of roughly approximate calculation that they are all of the same size. They will, therefore, have uniform bearing surfaces upon each other. If it were possible to stack enough of these brick on top of each other to make a column 100 feet high the bottom brick would be bearing a total load of not more than 2,400 pounds, or about 100 pounds per square inch. If the brick were laid in a wall and a small allowance made for the mortar which, bulk for bulk, is probably somewhat heavier than the brick, a height of over 400 feet could be reached before the weight upon the lowest courses would approach 500 pounds per square inch. In all modern construction of large office buildings no additional

load is put upon the walls by the floor steel, in fact, much of the weight of the brick work is customarily carried by the steel itself. It is thus apparent that only in case of a wall of enormous height, taller by several times than the tallest of office buildings or the Washington Monument, would the lowest brick be subjected to more than a small fraction of what they are entirely capable of bearing safely. The weakest of the brick tested from Oregon yards resist compression to as high as 1,100 pounds per square inch. So far as crushing strength is concerned, therefore, it is apparent that even these could never be dangerously loaded in the very highest of building construction. In fact, so large is this factor of safety in practically all marketable brick that a figure expressing the ability of brick to carry weight ceases to possess much, if any, significance.

The crushing test for the purpose of indicating strength is thus seen to be an unnecessary one, for it is very rarely that brick possessing any merit whatever will be barred out because of too low a compressive resistance. In so far as it renders comparison possible between different brick when taken with the results of other tests; and to the extent to which it discloses structural peculiarities or defects due to raw materials or method of making which might influence its resistance to frost action or to the action of the weathering agents, this test is to be regarded as serviceable. It is, however, a comparatively costly means of obtaining most of these facts, since they can, in many instances, be observed through much more simple ways than a machine test.

ABSORPTION TEST

The purpose of the absorption test is to furnish a relative numerical value that will express in a general way the readiness with which a brick will take in moisture when it is exposed to moisture-laden atmosphere or to falling rain in the wall of a building, or to moist or wet soils as in a foundation. It is highly essential that this factor be known in the case of brick to be used in rainy climates, and particularly where freezing temperatures frequently occur following or alternating with periods of rainfall.

The rapidity with which a brick will absorb water and the amount it can take determine the extent to which the outer courses will transmit moisture to the inner portions of a wall during wet seasons. The amount of pore space in the brick, the shape, size and number of the individual pores and the nature of the channels

connecting them all have a part in directing the movement of absorbed moisture. In general, the greater the porosity the larger the amount of water absorbed, but it is not correct to assume that the water taken up is a measure of the open pore space in the brick. In some cases it may be, in others not. The total porosity is not an item of great concern, however, since it is only the amount of space within the brick which water can and will ordinarily enter, as indicated by its absorptive power, that it is of practical value to know.

A very important feature of the absorption quality of brick is the rate at which water will pass into them from the absorbing surface. This phase of the matter is one that should receive consideration in employing brick for the walls of buildings, particularly dwelling houses in regions of continuous rainfall from a prevailing direction, or of dashing showers interspersed with short drying periods. The practical value of this knowledge is apparent in that the absorptive power of the brick largely determines or controls the appearance of moisture on the interior walls of the buildings with the attendant damaging effects. The appearance of efflorescences, or 'whitewash,' and other discolorations due to soluble salts, on the exterior of building walls, is also in part controlled by the ability of the brick to absorb water.

Aside from the actual amount of porosity, the 'openness' of the texture and the character of the open spaces themselves have largely to do with the readiness of absorption. As a rule, the coarse-textured brick absorbs water quickly in large quantity, while the fine-grained, dense appearing brick is slow to absorb, even though the actual porosity of the latter may be greater and its absorption, though slow, ultimately larger. The time element is thus a chief factor.

A knowledge of the absorptive power of brick is of especial advantage also in countries of freezing weather. When water changes from liquid to solid at the freezing point, it expands about 9 per cent in volume. The expansive force due to this change is stated to be equal to a pressure of over 2,000 pounds per square inch. If the freezing water is in such a position that its tendency to increase in size meets resistance, a very strong disrupting pressure is exerted. Broken water pipes and leaky automobile radiators in the winter time are familiar illustrations of the result of this well-known characteristic of freezing water.

When a porous brick saturated with water is subjected to a lowering temperature, the water in its pores expands at the freezing point and thus exercises a disintegrating tendency upon the structure of the brick. Its actual effect upon the integrity of the brick as a whole is determined by a number of factors important among which are, the amount of water contained as determined by the absorption test, the openness of the texture of the brick and its cohesive strength. A coarse-grained brick whose pore spaces are probably large and connected, although it may be weaker according to strength tests, will frequently withstand intact the action of frost throughout long periods of time. This, for the reason that the large size of the individual openings permits the brick to relieve itself readily by the movement of the solidifying ice from pore to pore with no damage to the brick, little spicules coming to and finally pushing beyond its outer surface where they appear as a frosty coating. In a closer textured brick, the pores are smaller and less well connected, the channels for movement are narrower and more tortuous. In this case the entire expansive force of the freezing water is spent in pressing against the cell walls and the cohesive strength of the particles composing the brick becomes the factor that determines the extent to which it will disintegrate. Bricks of the latter type are frequently much more seriously acted upon by frost than the open textured variety. In any case the quality of the material of the burned brick has as much as any other one factor to do with its frost resistance. Quality is determined in part by the raw materials used, but more by the homogeneity of their arrangement in the made brick and their proper fixation by burning to a degree of sufficient hardness. The harder the burn, the less the pore space in the brick, hence the lower the absorption will be.

The absorptive ability of brick affects to some extent the adherence of mortar both when they are being laid and after the mortar has set; a medium degree of porosity at least being considered favorable from this standpoint. Adherence of the mortar to the brick is a desirable feature, both facilitating the work of the mason and contributing to the solidarity of the finished wall. This factor is one of minor importance, however, in comparison with the other qualities for which the absorption test is applied. Cleanliness is an item of moment, the more open-textured brick permitting the lodgment of dust, soot, etc., in their pores, thus spoiling their appearance. The porous brick is, on the other hand, a poorer conductor

of heat than a dense one, therefore a better insulator against the weather or in case of fire.

The absorption test, in itself, therefore, shows only how much water a brick will take up and how rapidly moisture will pass into it. Its usefulness is greatest, as pointed out, only when used in conjunction with the results of other tests, particularly the crushing and freezing and thawing tests.

The absorption tests on Oregon brick were made by first weighing dry, and then after saturation the 5 half-brick previously referred to as being used in the wet crushing test. The difference between the wet and dry weights, or the weight of water absorbed, expressed as a percentage of the dry weight is called the percentage of absorption. The method employed was to submerge the dry half-brick in water, then heat to boiling within one hour and boil continuously for four hours, in accordance with the proposed American Society for Testing Materials standard specifications.

FREEZING AND THAWING TEST

The freezing test should be a valuable one, as has been pointed out, on brick to be used in damp climates of freezing weather. It is occasionally, though not at all uniformly made in testing building brick. The customary method of procedure is to alternately freeze and thaw half-brick or two-inch cubes that have been soaked in water, from 20 to 30 times, or until they begin to show disintegration. Repeated weighings are made to ascertain loss by spalling or crumbling as the test progresses. The freezing test was not made on Oregon brick.

A number of other tests are applied to building brick of certain types or when they are to be used under special known conditions.

The fire test is one of great value. A simple method of making this test is to heat to redness in a furnace a sample brick and plunge it into cold water, noting any cracks or other weakening effects upon it. The fire test has been carried out on a larger and more practical scale by heating to strong redness a panel several feet square made of brick laid in mortar. Against this panel while red-hot a stream of water is directed under heavy pressure for several minutes. The resistance of such a panel to this treatment is required as an indication of the ability of the brick under test to withstand both heat and water conditions such as would occur in a burning building.

All of the tests of Oregon brick here reported, also those of drain tile and building blocks that follow, were made in the laboratory of the department of Experimental Engineering, Oregon Agricultural College. Part of the work was done by Messrs. S. W. French and G. J. Mitchell of the Bureau corps, and part by Professor S. H. Graf and his assistants, Messrs. Knopf and Boals. The writer gratefully acknowledges the courtesies of these gentlemen, whose labor and painstaking care in performing the tests have contributed very largely to the value of the results obtained.

THE BRICK TESTED

The following firms kindly furnished samples of brick for testing.

Albany Brick & Tile Company, Albany
Baker Fire Clay Company, Baker
Bend Brick & Lumber Company, Bend
Cofer Brothers, Klamath Falls
Columbia Brick Works, Portland
W. O. Cook, Eugene
Corvallis Brick & Tile Works, Corvallis
Dallas Brick & Tile Company, Dallas
Fairmount Brick & Tile Company, Monroe
E. A. Gleason, Cottage Grove
Goode & Van Hoomissen, Donald
Hollywood Brick Yard, Salem
Hoskins & Desart, Donald
Jacksonville Brick & Tile Company, Jacksonville
L. E. Kern, Portland
Wm. Kruger & Son, Oregon City
La Grande Brick Company, La Grande
McMinnville Brick & Tile Company, McMinnville
Mt. Angel Brick & Tile Company, Mt. Angel
Pacific Face Brick Company, Willamina
Penitentiary, Salem
John Preschern, Springfield
D. B. Provost, Ashland
Salem Tile & Mercantile Company, Salem
George F. Shew, Monmouth
Standard Brick & Tile Company, Portland
Tillamook Clay Works, Tillamook
Tolo Brick & Tile Company, Tolo
Weston Brick Yard, Weston

Individual reports of the results of the brick tests have been sent to each manufacturer. By consulting the accompanying tables and diagrams, each set of results will be found where it may be compared with the figures from other tests. Each figure given in the tables is the average result from 5 samples except as noted otherwise.

It will be noted that three tables (I, II, III) have been made giving the results for stiff-mud, soft-mud and dry-press brick respectively.

TABLE I. TESTS OF STIFF-MUD BUILDING BRICK MADE IN OREGON.

Set No.	Kind of brick	Percentage of water absorbed	Cross-breaking test		Crushing test Strength in lbs. per sq. in.		Strength ratio =crushing strength ÷ modulus of rupture	Remarks
			Total breaking load in lbs.	Modulus of rupture lbs. per sq. in.	Brick tested dry	Brick tested wet		
1a	"Plastic Red".....	12.8	1,368	921	6,840	6,414	7.4	Perforated brick. Holes allowed for
1b	"Colonial Brown".....	9.5	2,280	1,118	6,868	6,856	6.1	
1c	"Light Buff".....	16.6	1,758	988	6,470	7,268	6.5	Perforations allowed for
1d	"Dark Buff".....	13.7	2,206	1,340	9,038	8,670	6.7	
1e	"Plastic White".....	14.0	2,694	1,160	7,036	5,470	6.1	Perforations allowed for
2	Red.....	20.7	1,124	522	2,296	2,844	4.4	
3	Red.....	21.6	374	163	3,768	3,282	23.1	Modulus average of but 4 brick Only 4 half-brick crushed dry
4	Red.....	28.7	2,737	1,241	5,014	4,858	4.0	
6	Red.....	20.9	1,232	598	1,998	2,608	3.3	Only 4 half-brick crushed dry
8	Red.....	17.5	1,566	735	3,780	3,042	5.1	
11a	Buff "Fire Brick".....	20.0	796	406	1,386	1,429	3.4	
11b	Brown Mottled.....	20.4	1,396	668	1,740	1,651	2.6	
12	Red.....	18.8	1,878	907	4,376	3,836	4.8	
13	Red.....	21.9	1,292	621	2,927	3,012	4.7	
15	Red.....	15.4	850	518	4,078	4,340	7.8	Re-pressed brick
18	Red.....	17.7	990	488	2,818	2,765	5.8	
19	Red.....	15.8	1,858	839	4,264	4,362	5.1	End-cut brick
20	Red.....	25.1	730	397	1,814	1,811	4.6	
21	Red.....	19.9	1,854	832	4,152	3,988	5.0	Only 4 brick in transverse test
30	Red.....	25.4	375	232	1,432	1,497	6.2	
Tests of Foreign Brick for Comparison								
Average of 3 tests of western Canada brick.....		19.8	928	481	2,288	.....	4.7	
Average of 22 tests of Wisconsin brick.....		20.26	.....	1,027	4,244	.....	4.1	
Average of 14 tests of New Jersey brick.....		11.05	.....	824	3,630	.....	4.4	

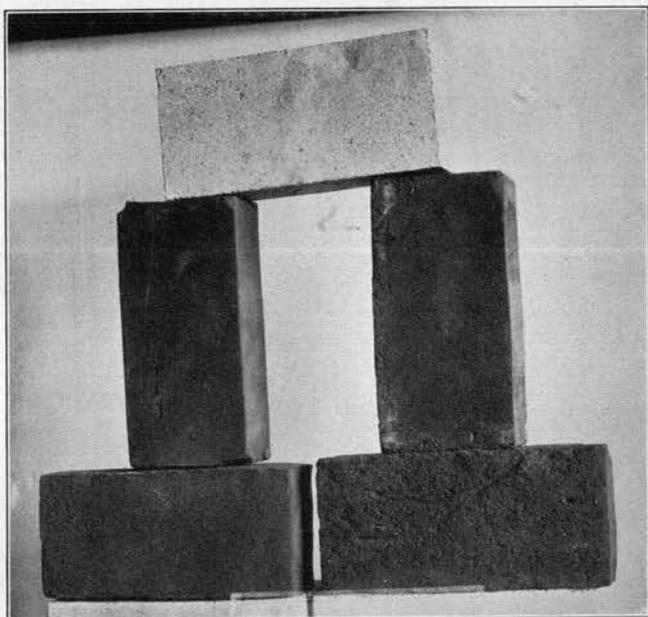


Fig. 8. The three common kinds of clay building brick. The two at the bottom are soft-mud brick, the one at the left showing the sanded surfaces produced in the mold, and that on the right the top or "struck-off" surface of the brick. The two on end are stiff-mud or auger machine brick, that at the left an end-cut and the right the side-cut brick. The brick of lighter shade at the top is the dry-press product, its characteristically true shape and sharp corners and edges being notable.

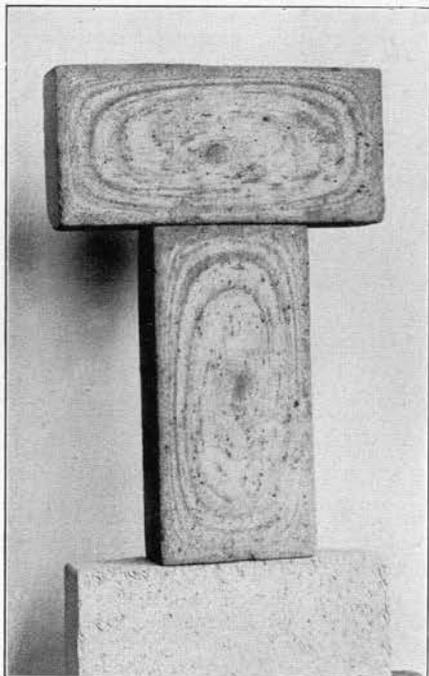


Fig. 9. Stiff-mud brick showing laminations. In these particular brick the spiral structure produced by the auger is pronounced on account of the mixture of a red and a light burning clay.

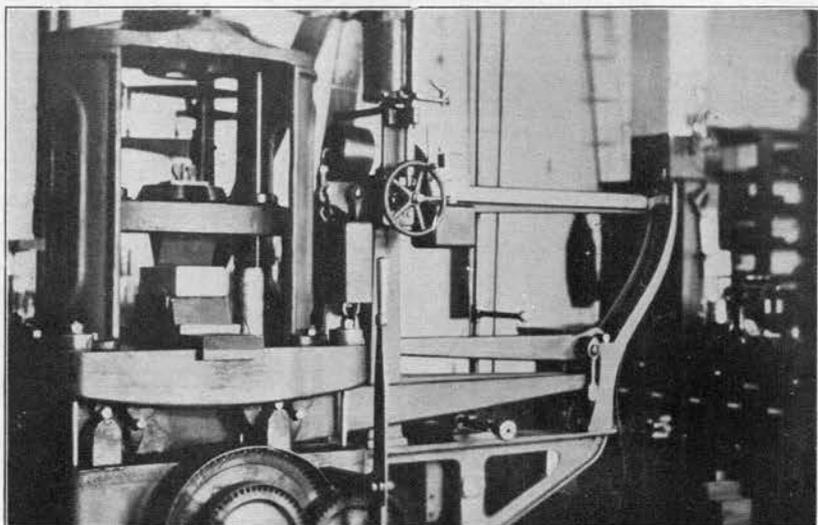


Fig. 10. Building brick in position for making the cross-breaking test. Notice the knife-edge through which from above pressure is applied across the brick at its middle point, the brick being supported below on two similar rounded edges.

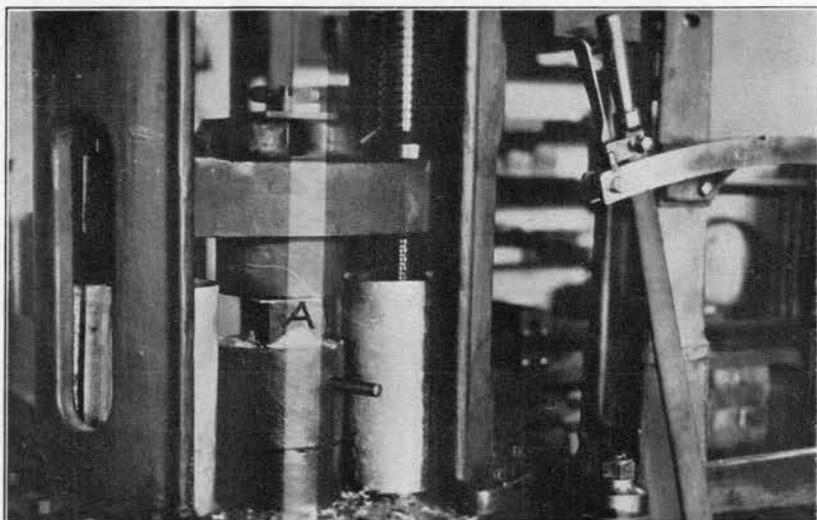


Fig. 11. Half-brick in position (A) for crushing test. The brick is embedded in plaster both above and below between two heavy steel bearing plates.

Stiff-mud brick are made on an auger machine, the clay being worked up with water in a pug-mill to a stiffly plastic condition. Soft-mud brick are made either by hand or by means of a machine which presses the clay that has been mixed up to the consistency of a soft mud, into sanded molds. Dry-press brick are made

TABLE II. TESTS OF SOFT-MUD BUILDING BRICK MADE IN OREGON

Set No.	Per-centage of water ab-sorbed	Cross-breaking test		Crushing test Strength in lbs. per sq. in.		Strength ratio =crushing strength ÷ mod-ulus of rupture	Remarks
		Total break-ing load pounds	Modulus of rupture lbs. per sq. in.	Brick tested dry	Brick tested wet		
5	25.0	706	355	1,718	1,508	4.8	
7	22.9	994	494	2,122	2,393	4.3	
9	29.5	406	207	1,144	1,151	5.5	
10	49.6	844	360	1,255	1,407	3.5	
16	26.9	974	498	1,946	2,305	3.9	
17	21.6	1,012	490	2,868	3,113	5.1	
22a	18.2	1,348	699	2,761	2,749	3.9	
22b	17.4	1,362	732	2,702	2,263	3.7	Panel re-pressed brick
23	22.5	472	242	1,186	1,152	4.9	
24	21.3	652	295	1,467	1,374	4.9	Only 4 brick tested
26	20.8	675	334	1,851	1,702	5.5	
27	19.4	1,368	727	2,581	2,450	3.6	Rather hard-burned
28	19.85	934	515	2,772	2,571	5.4	
29	21.7	1,328	699	3,524	3,327	5.0	
Tests of Foreign Brick for Comparison							
Average of 22 tests of Wisconsin brick	18.60	.....	575	2,829	.....	4.0	
Av. of 8 tests of western Can. brick..	20.7	1,015	507	2,178	.....	4.3	
Av. of 18 tests N. Dakota brick.....	20.4	.....	692	1,961	.....	2.8	

in a machine by applying very heavy pressure to the moistened clay which either occurs naturally in the right condition or has been previously pulverized to a granular state and mixed with a small proportion of water. As a general thing, clays suited for making one of these three classes of brick are not very satisfactory for either of the others, although there are some exceptions to this rule. Figure 8 is a photograph showing the appearance of each of the three varieties of brick.

DISCUSSION OF RESULTS

A careful examination of all of the results given in the tables appears to show certain general relationships to which it is worth while to call attention. It appears that the average crushing strength of the soft-mud brick is the lowest of the three, as is also the modulus of rupture. The highest moduli of rupture and the greatest crushing strengths are found among the stiff-mud brick. The number of dry-press brick tested is too few to expect to discern any general relationship of properties as compared with the other varieties. Dry-press brick very frequently possess higher strengths than stiff-mud products, however, and comparatively low absorption, as is shown by the "Dry Press Gray" in table III and the figures given for brick from other states.

Again it will be noted that in general the modulus of rupture increases with increase of crushing resistance, also that the percentages of water absorbed vary up and down with the crushing and cross-breaking strengths.

Some attempts have been made in similar tests made elsewhere to rank the brick according to their quality. On the basis of only the three tests, cross-breaking, crushing and absorption, this has always been found unsatisfactory or impossible. No constant or uniform relationships among these three factors has been seen to exist in any series of tests yet made. In order to properly classify a brick as to its quality, first of all the conditions under which it is to be used must be known, second, a familiarity must be gained with the nature of the raw materials and processes of manufacture employed, and these must be considered in conjunction with the results of the above tests. Quality is relative only. A brick suited to one locality, climate or position, may rank very low for another, while one well adapted to the second set of conditions may reciprocally be seriously unsuited to the first. Again a brick carefully made and burned to a certain degree of hardness may serve well for one purpose while the same brick may be rendered either useless, or available for a much wider range of application, by being burned to a different heat in the making.

So far as the results given are concerned, therefore, effort has been made only to so picture them by means of two diagrams that the salient facts that they do show may be more clearly brought out. In the diagram on page 31, the center of each circle is so located on

TABLE III. TESTS OF OREGON DRY-PRESS BRICK

Set No.	Name of brick	Percentage of water absorbed	Cross-breaking test		Crushing test Strength in lbs. per sq. in.		Strength ratio =crushing strength ÷ modulus of rupture	Remarks
			Total breaking load pounds	Modulus of rupture lbs. per sq. in.	Brick tested dry	Brick tested wet		
1g	"Dry Press Gray".....	14.1	2,064	973	5,916	4,986	6.1	Panel brick
1f	"Fire Brick".....	15.3	1,564	633	2,084	2,442	3.3	
Tests of Foreign Brick for Comparison								
Average of 15 different tests of Texas brick.....		10.25	.....	.....	5,231	.....	.....
Average of 5 different tests of western Canada brick.....		16.1	999	472	3,431	.....	.....
Average of 6 different tests of Wisconsin brick.....		21.47	.....	512	3,408	.....	.....

the coordinates as to indicate both the crushing strength in pounds per square inch and modulus of rupture of each set of bricks tested. The size of the circle indicates the relative amount of water absorption as shown in the tables. The smallest circles thus mean lowest absorption and the larger the more absorbent brick. A glance at this diagram will reveal that, in general, the soft-mud brick, having the largest circles, group themselves rather closely at the lower left in the region of lower strengths. The stiff-mud brick are more scattered and have a broader range of absorption, intermingling to some extent with the soft-mud circles, but the majority of them having both higher modulus and greater crushing strengths. The number at each circle is the 'Set No.' given in the table to which reference may be quickly made.

It may be worthy of remark that in general the half-brick crushed wet were less strong than those broken dry. This is not universally true, however. In the case of the soft-mud brick, quite a number of those in which the wet sample was stronger than the dry, also showed the higher percentages of absorption. Nor is this uniformly the rule. In other reports of brick tests discussion has been entered into of the influence of saturating the brick before testing and its advisability as a standard test. As has been pointed out on an earlier page, the crushing test as a measure of strength is of little value since brick are rarely loaded to anywhere near their carrying capacity in use. For this reason, and since uniform conditions or degrees of saturation, or the effects of continued soaking, can be much less readily taken into account, there seems no thorough-going reason for making other than the dry crushing test in which standard and constant conditions are more easily produced and maintained.

Careful consideration of the climatic conditions in Oregon and neighboring coast states will suggest to the reader that the ability of brick of otherwise acceptable quality to absorb water is a factor of prime importance. To arrange the Oregon brick tests in the order of their absorptive power, the diagram on page 33 is constructed. This diagram shows also the general relation already pointed out between water absorption and strength. In order to obtain a single factor which could stand for the strength of the brick the 'strength ratio' is used. It is obtained by dividing the average crushing strength by the average modulus of rupture, for each set of brick. This division is justified since it is noted that as

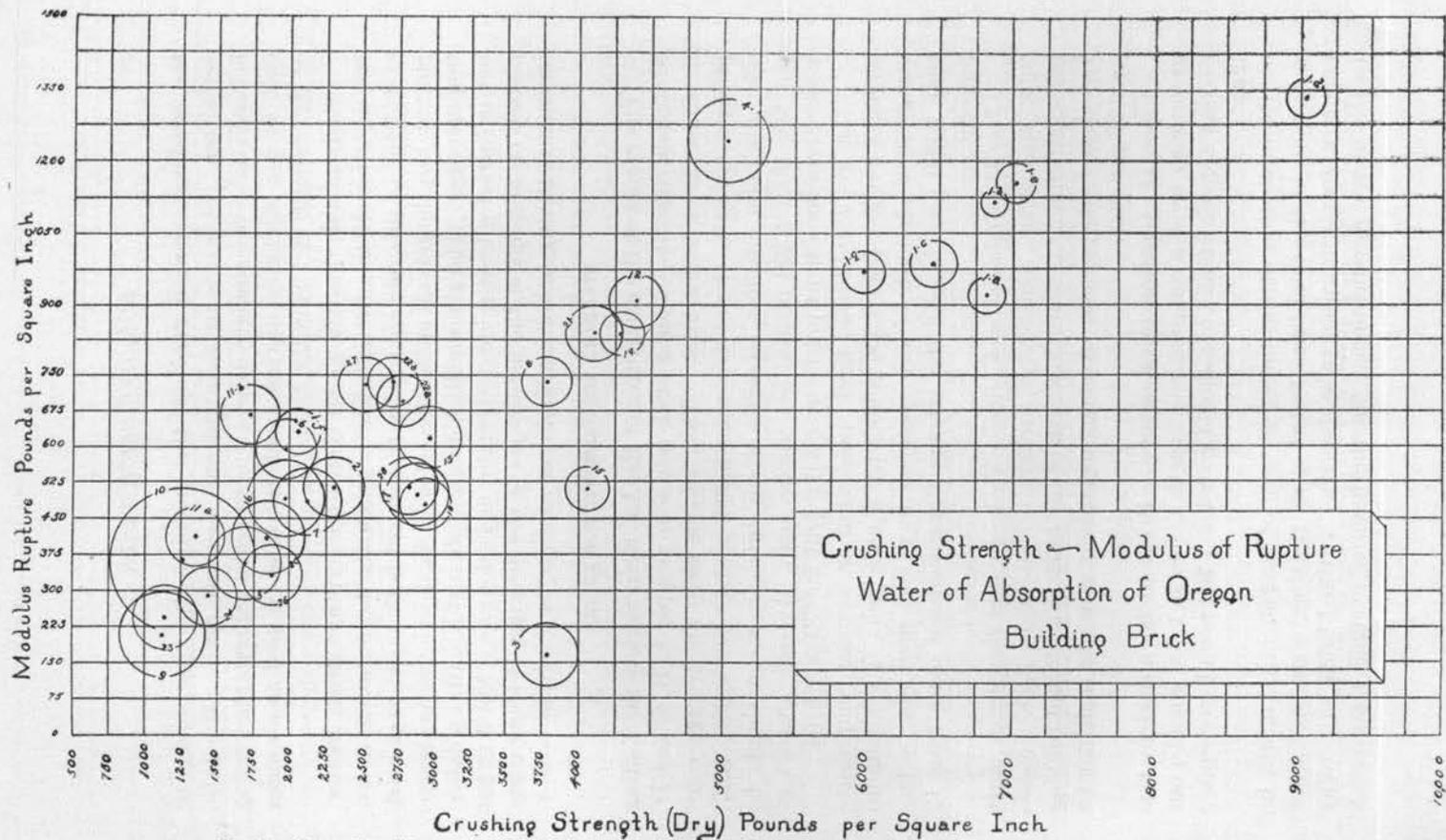


Fig. 12. Properties of Oregon building brick. Small circles indicate low absorption; large circles high water absorption.

the crushing strength goes up, the modulus also rises, and vice versa, but not so as to maintain any constant ratio. The ratio between these two strength figures is in general a uniformly increasing one, as the strengths increase, and can thus be used as an index of the strength factors in the diagrams.

Study of this diagram shows that, as absorption grows greater, the direction of the strength line is gradually downwards. A few exceptions to this rule are seen in the case of both varieties of brick plotted, but the general inclination is for strength to lower as absorption increases. The abnormally high absorption of No. 10 is notable, but it carries with it a lower strength, as is the rule. No. 3 is not plotted on account of the limitations of the drawing, it being quite unusual in having so low a modulus of rupture, as shown in table I.

STANDARD REQUIREMENTS FOR BRICK

The report of the committee of the American Society for Testing Materials classifies building brick into four groups, A, B, C and D.

Class A—*Vitrified* brick. They should have an average compressive strength of not less than 5,000 pounds per square inch. The minimum crushing strength of any brick in a test should be not less than 4,500 pounds per square inch. Average amount of water absorption must not be over 5 per cent for Class A brick.

Class B—*Hard-burned* brick, possessing an average compressive strength not less than 3,500 pounds per square inch. The minimum compressive strength of any specimen in a test shall not be less than 3,000 pounds, and the average absorption not more than 12 per cent.

Class C—*Common* brick, first. To be in this class brick must show an average compressive strength of not below 2,000 pounds per square inch, the lowest strength of any brick in a test not running less than 1,800 pounds. Average absorption of water shall not be over 18 per cent.

Class D—*Common* brick, second. Brick to be placed in this group may show a compressive strength as low as 1,500 pounds, but no single specimen in a test should go below 1,200 pounds per square inch.

By inspection of the tables of tests of Oregon brick it will be seen that, of the total brick tested of all varieties, none have a low enough average absorption to be classed as "vitrified brick" according to the above specifications. On the basis of average compression

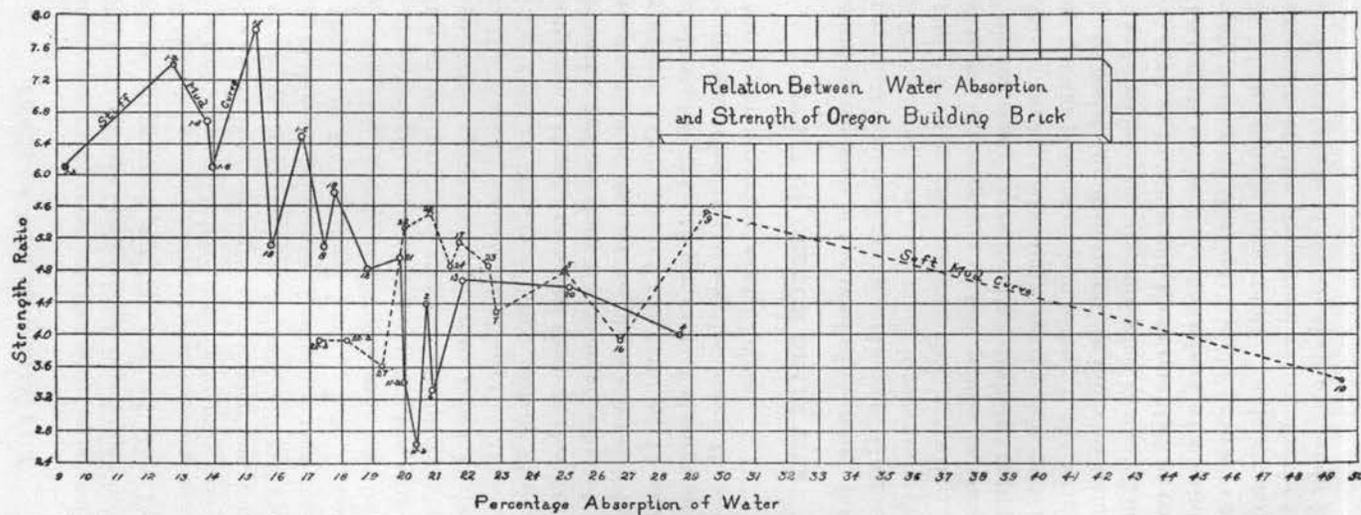


Fig. 13. Strength and absorption of Oregon brick. In general, the more absorbent brick possess the lower strengths. Results of tests of stiff-mud brick shown by the solid line in the diagram; of soft-mud brick by the dotted line. Figures at turn-points of curves are the 'Set Nos.' given in accompanying tables.

strength alone, however, seven of the sets tested would enter this class. Of the nine average foreign brick listed none belong to class A on the basis of absorption and but one set (the Texas brick) in compressive strength.

Class B, "hard-burned brick" can claim only one set of Oregon brick, according to both strength and absorption, but on the basis of average crushing strength alone, below the lower limit of Class A, six different makes of brick would come in this class. With one exception, these are all stiff-mud brick. Into Class C, "common brick first," will fall 11 sets of Oregon tests on the basis of both absorption and strength, and all but one are the stiff-mud product.

According to the proposed standard requirements given above, more Oregon brick appear to pass into Class D, "common brick second," on the basis of amount of absorption than into any other group. Of the total of 36 sets of brick tested, 24 give over 18 per cent of absorption. It is to be noted that, of this 24, 19 show compressive strengths greater than the average allowed for this class, and 12 of these are high enough to place the brick in Class C or a still higher group. Only one of the total of 14 sets of soft-mud brick tested shows less than 18 per cent of absorption. Four out of the 14 sets possess crushing strengths lower than the minimum allowed in the "common brick second" class.

TESTS OF OREGON DRAIN TILE

A beginning recognition of the need of thorough farm drainage in large portions of the main farming sections of Oregon, and the use of drain tile for this purpose, have made it necessary that the Bureau of Mines and Geology give considerable attention to their production and to an investigation of the quality of Oregon-made tile. The use of tile for many years in other drainage regions has demonstrated that, in order to be both serviceable and lasting in the ground, they should possess certain strength characteristics, as well as an ability to resist any disintegrating influences coming from the soil conditions to which they are subjected in use. Tile tests should, therefore, be such as to bring out these qualities of resistance.

While the nature of the raw materials of which the tile are made has very largely to do with their quality, the processes of manufacture employed are about equally important. To determine, therefore, in an intelligent manner the properties of the finished product, not only should the materials of which they are made be known and

taken into consideration, but also the methods of making, as well as the ware itself. Logically, a detailed study of the product should be the first step, whether the final purpose be merely to ascertain its quality or to discover the need and means of improvement.

Drain tile were used for many years before any definite determinations were made, or thought given to what the characteristics are that make them efficient and durable. They were first made of clay and only in the smaller sizes. Of late years larger and larger tile are being used. This fact, and the advent of the concrete tile as a serious competitor to the clay-made article, have emphasized the necessity of recognizing just what the cardinal properties of a tile are, and of developing systematic methods of expressing them.

As in the case of building brick, a committee composed of engineers and of tile manufacturers and users, of the American Society for Testing Materials, has been at work for the past few years on this question and has drafted a set of tentative standard specifications which have been adopted by the society. These specifications outline in detail the tests that should be applied to tile, the methods of making them, and state the definite requirements within the limits of which acceptable tile should range. The recommendations of this committee are the result of a protracted series of tests and are now the standard by which all comparable tests of this kind should be made. The tests the results of which are given on a later page were made on both clay and concrete tile, the method of procedure in testing being essentially that recommended by the American Society.

The tests made were but two, namely, the direct strength or crushing test and the absorption test. Making use of the data derived from the crushing test, a third factor was obtained, as shown in the tables and diagrams, the modulus of rupture of the material composing the tile walls.

CRUSHING TEST OF DRAIN TILE

By the crushing test is meant the determination of the actual amount of vertical pressure required to produce collapse of a tile placed in a horizontal position. Its purpose is to provide a definite figure which will express the ability of the tile to resist or support the weight coming upon it when it is placed beneath the surface of the ground in a drainage line.

The source of the weight that comes upon a tile is the ditch

filling, and this load is greatest when the tile are first laid. In all newly-filled trenches of ordinary width and depth practically the full weight of the filling material rests upon the tile. The latter should, therefore, be sufficiently strong to carry this load with a reasonable margin of safety to allow for possible saturation, therefore added weight of the material, when the tile are first covered. As the age of the drain increases, the load on the tile probably diminishes, due to the compacting of the filling and the consequent ability to support itself by amalgamation with the materials of the former ditch walls. The tile must, however, be amply strong to withstand this maximum first load.

The amount of load on tile in ditches has been the subject of a thorough investigation by the Engineering Experiment Station of the Iowa State College. Actual determinations were made of the pressure on tile at varying depths and widths of ditch and with a number of different common filling materials. It was found that the load on the tile from the weight of the ditch filling increased with the depth of fill, but that the rate of increase is lower as the depth becomes greater. That is to say, for example, that a foot of soil put into the trench when it has been filled to three feet above the tile will add less weight upon the tile itself than would the first or second or third foot of fill. A limit to this increase of load is found when the fill becomes equal in depth to 10 times the breadth of the ditch at the top of the tile, beyond which practically no additional pressure is put upon the tile by further filling. At this point the friction against the walls of the ditch becomes great enough to bear the weight of any additional load. Thus a pipe or tile laid in a ditch 12 inches wide and 10 feet deep will have a greater load to bear than the same tile at three feet, but no greater than a tile would have where a cut of 11 or 12 feet might be necessary. This fact, it is apparent, it is important to remember in case large tile are being used and deep cuts made. In ordinary drainage work in comparatively level regions, however, this depth limit of loading is probably reached only occasionally and in exceptional cases.

The further fact was, however, brought out by the investigation referred to, that, in ditches with vertical walls and of customary proportions, as much weight comes upon a small as upon a large tile. A 6-inch tile will have to carry as much load as a 10-inch in the same trench. That being true, the advisability of making deep trenches, for large tile particularly, as narrow as possible, is

strongly emphasized. If wide trenches are narrowed as the bottom is approached, weight is taken off the tile in proportion to the decrease of width.

The weight which rests on a tile when it is laid depends also upon the nature of the filling material. Sandy clays are the heaviest of common fillings, humus top-soil the lightest, while sandy and clay loams are intermediate in weight. The weight of earth materials is commonly expressed in pounds per cubic foot. Damp top-soil of the silt or clay loam varieties such as many of the valley soils of Oregon are, of usual compactness, will weigh 85 to 90 pounds per foot; saturated with water, 100 to 110 pounds. Silts and loam soils from below the surface will run somewhat higher than these figures. Certain volcanic ash soils such as predominate over large areas in parts of eastern Oregon, and particularly those of the pumiceous variety, are comparatively light, weighing frequently less than 100 pounds per cubic foot when saturated. The loads that tile must carry, therefore, are directly proportional to these weights per cubic foot, but lessened by the friction of each against the sides of the trench, as already pointed out. Where large tile or pipe are to be used a full knowledge of the weight of the filling along with its coefficient of friction is essential to a successful installation. Further discussion of these points will not be entered into here. A large quantity of valuable data on this matter is to be found in bulletin No. 31, published by the Iowa State College Engineering Experiment Station.

METHODS OF MAKING CRUSHING TESTS OF DRAIN TILE

Several different methods are employed to determine the resistance of drain tile to crushing weights. The simplest, least expensive, as well as least accurate method, is probably the crude one of piling upon the tile placed in a level position, an increasing number or quantity of heavy materials until it goes down beneath the load. Bags of cement or sand, or of earth, are convenient and frequently used for this purpose. By weighing the total load required to cause the collapse of the tile its supporting strength is obtained directly.

The more accurate and refined means of making tile tests is by the application of the breaking load in some type of testing machine. There are three machine methods used and known among drainage engineers and tile manufacturers as (a) sand bearings, (b) three-point, and (c) hydraulic bearings methods. All three methods are

recognized by the American Society for Testing Materials and are in practical use in the various drainage sections of the country.

The hydraulic method was originally developed by Mr. Mont Schuyler, of the Municipal Testing Laboratory of the city of St. Louis, and is used by him in the large number of pipe and tile tests made in that laboratory. The photograph (fig. 16) shows this method of testing. Both the upper and the lower bearing is a piece of large fire hose partly filled with water, the ends being kept closed tight by clamps. The pressure is applied by means of the wooden beam in a standard testing machine. An advantage which is claimed for this method is that the slightly yielding hose bearing surfaces permit of the application of an even pressure over the full length of the tile, even when the tile is slightly distorted or its shell somewhat rough, pebbly, or pimped in burning.

The three-point method is illustrated in figures 17 and 18. The tile is placed on two half or quarter-round strips nailed about two inches apart on a 4 x 4 timber. The upper bearing is the flat under-surface of a 4 x 4. These bearing surfaces may be so adapted that the breaking load can be applied in a standard testing machine. The Oregon tests were made by the three-point method in a 50,000-pound Riehlé Universal machine.

Special machines are also designed in which the three-point plan is employed. Mr. C. W. Boynton, of the Universal Portland Cement Company, of Chicago, has designed the so-called 'Universal' machine. In this machine, whose frame is of steel, the lower bearing rests on a scale platform, or on a pair of levers that transmit a portion of the pressure to the scale platform. The load is applied by forcing the top bearing downwards with a hand-wheel that operates a vertical screw shaft. This machine is built by the Quinn Iron Works, of Boone, Iowa, and is meeting a wide use among the users and makers of both clay and concrete tile throughout the middle states.

A three-point machine has also been built by Professor A. N. Talbot and D. A. Abrams, of the Engineering Experiment Station of the University of Illinois, customarily referred to as the 'Illinois' machine. The frame is of wood and the load is applied in this machine by weighting the outer end of a lever whose fulcrum is six inches back of the upper bearing.

It will be noted that, in this method, the actual contact of the tile with its bearing is, if the tile be perfectly true, three lines, the

two on which it rests below and a line of contact with the plane surface of the timber above. Any irregularity, therefore, in the shape of the tile under test, as warping or roughness of surface, will prevent a perfect contact of the bearings against the tile throughout its length. Although this is true, it is found, nevertheless, that the presence of slight irregularities in the tile does not usually affect the results of a test to any important extent. Distortion of form or defect of surface to such a degree as to vitiate the results by this test are to be properly regarded as factors affecting the quality of the tile; therefore, such as should preferably be disclosed in the breaking test. This method of testing is one easily and quickly carried out at little expense for additional equipment where a standard testing machine is available, and, at no great cost in comparison with the value of the results, when it is necessary to procure the specially made machine.

The sand bearings method was originally devised by Director A. Marston, of the Iowa State College Engineering Experiment Station, and has been used and recommended for several years by that station. A cut which illustrates the principal of this method is

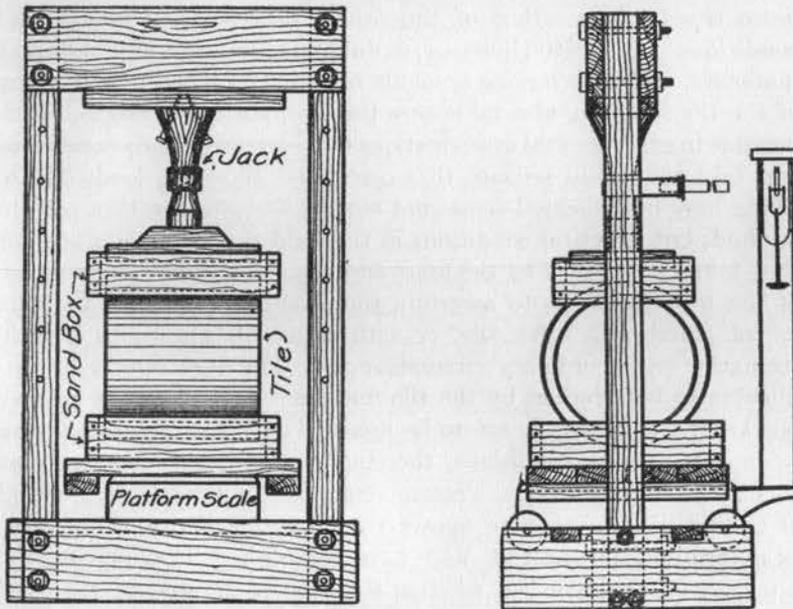


Fig. 14. Sand bearings method of testing drain tile. Photo loaned by Director Iowa Engineering Experiment Station.

given on page 39. The tile to be tested is embedded in sand both above and below for one-fourth of its circumference. In the specially constructed machine for testing the smaller sizes of tile, pressure is applied through the top sand bearing by means of a screw jack actuated by a hand lever. The lower sand-box either rests upon a scale platform or a system of levers is so arranged that a fraction of the weight is transmitted to a scale at one side. The sand bearings may also be used in connection with any regular compression testing machine. It is only necessary to adapt the sand-boxes to fit the particular machine to be employed. For regular use, where it is frequently desirable to move the machine from place to place, the specially made frames, as shown in figure 00, are to be preferred. They are entirely of wood, can be made by any carpenter, and, according to the Iowa Engineering Experiment Station, of Ames, Iowa, which offers to supply plans on request, the different sizes can be built at costs averaging from 20 to 95 dollars.

It is held by those who have developed the sand bearings method that with it the tile are tested under loading conditions similar to those to which they are subjected after they are laid in a drain. Actual results prove that it does imitate the conditions in the ditch more closely than either of the others described. Underground conditions vary greatly, however, in different localities, with different materials, and with varying amounts of water present. The bedding of the tile in laying also influences their supporting strength. It is possible in experimental investigations to so carefully study conditions and take them into account that calculated allowable loads due to filling may be indicated somewhat closely by testing with a certain method; but practical conditions in the field cannot be and are not thus taken account of by the users and makers of tile. The purpose of the test should be to ascertain the strength quality of the tile, as compared with other tile, or with standards known to be safe strengths under ordinary circumstances. The test should be applicable to his product by the tile manufacturer, who may or may not know where his tile are to be used. The actual value of trying to imitate service conditions, therefore, or of using the fact that such an attempt is made as a recommendation for a particular method of testing may be open to question. After safe limits of strength, as determined by the test, have been established, it should not be a matter of much concern whether the type of equipment employed applies pressure in one way or another so long as it gives uniform and dependable results.

While the sand bearings test thus possibly comes nearest to reproducing ditch conditions, it is the least simple to make, requiring not only the procuring and handling of the sand itself, but also lumber for the sand-boxes. Moreover, the care and adjustment necessary to adapt the bearings to successive tile, and especially to successive sizes of tile, are a factor in its use wherein whatever distinct advantages it may possess, may be in part lost through the untrained and sometimes unintentionally careless manipulation of the ordinary maker or user of drain tile. By actual timing, from one to seven minutes longer time is required to make the sand bearing test than with either of the other machines.

The conspicuous and undisputed advantages claimed for the sand bearings test, aside from the questionable one already discussed that it gives nearest to the real supporting strength of the tile, are: the use of sand renders possible the uniform distribution of the load over one-half the circumference of the pipe regardless of minor irregularities of shape or surface (it can also fail to bring out the effects of such irregularities as might properly be considered defects in the tile); accuracy (if skilfully operated); it permits of testing pipe having bells the same as straight pipe. The results obtained by the use of this method are referred to as the "ordinary supporting strength" of the tile.

THE TESTS OF OREGON TILE

Before making the crushing tests of Oregon drain tile, the tile were thoroughly soaked in water. The tile were thus broken after they had taken up practically all the water they would absorb. This method of procedure was followed, as recommended in the standard specifications, since the tile in the ground are always damp, or saturated, and in this condition are believed to be in general weaker than when free from moisture. Comparative tests have shown this assumption to be true with some clay tile and, so far as known, with all concrete products. Since a purpose of the breaking test is to afford a basis over which a reasonable strength factor of safety can be provided for, tile should be tested when they are in, as nearly as possible, the weakest condition that they will be after being placed in the ground. It is probable that a longer period of soaking should be allowed in later tests than was given before the present sets of tile were broken.

STRENGTH OF THE WALLS OF DRAIN TILE

Besides the supporting strength of tile it is of value to know something further as to the actual quality of the material of the tile walls. Along with the bearing of the weight of the ditch filling, tile in the ground are subjected to the constant wetting and drying action of the moist soil which surrounds them, the water that flows through them and in regions of cold, to the action of frost. A knowledge of the nominal tensile strength of the material composing the tile, such as is determined directly in building brick by the cross-breaking test, supplies a comparative clue to the ability of different tile to resist the influences just mentioned.

The modulus of rupture for drain tile is obtained from the result of the crushing test by the following formula, the derivation of which will not be given here.*

$$M = 0.20 R \frac{W}{12} \text{ and}$$

$$p = \frac{6M}{t^2}$$

in which

M = the maximum bending movement in the tile shell, in inch-pounds per lineal inch.

R = the radius of the center line of the tile shell in inches.

W = the "ordinary supporting strength" of the tile in pounds per lineal foot calculated by multiplying the breaking loads in strength tests by the following factors: sand bearings, 1.00; hydraulic bearings, 1.25; three-point bearings, 1.50. (Note: Five-eighths the weight of the tile per lineal foot for sand bearings, or three-quarters for hydraulic or three-point bearings, must be added to W in computing M whenever such addition exceeds 5% of W.)

p = the modulus of rupture of the material of the tile shell, in pounds per square inch.

t = the average thickness of the tile shell, in inches, at the top or bottom, whichever averages thinner.

To obtain the modulus of small tile, the more convenient expression, $p = \frac{RW}{10t^2}$ may be used, which is obtained by equating the above formulae and solving for the value p.

For calculation of the modulus of rupture certain careful measurements of the tile are thus required, as shown in the formulae, as well as the breaking strength, determined by one of the three machine methods of testing. This factor was calculated for each set of Oregon tile tested and is included in the tables of results given on pages 44 and 45. It is obviously a figure to which less importance should be attached in the case of tile to be used in a region such as

*Bulletin 36, Engineering Exp. Sta., Iowa State College, p. 87.

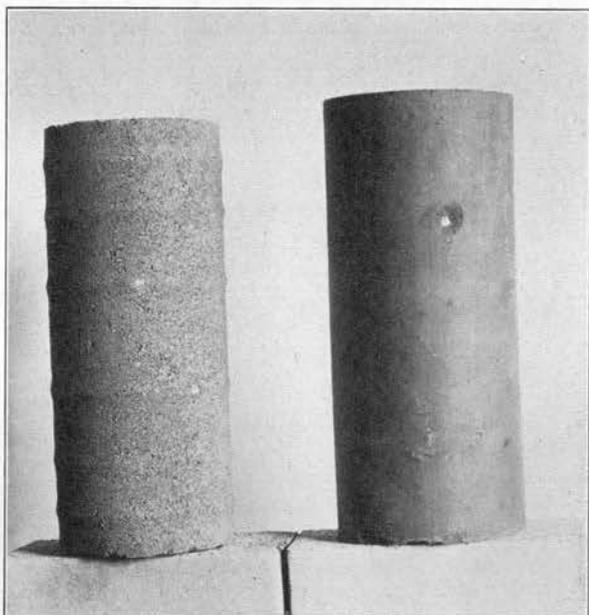


Fig. 15. Concrete drain tile at the left; clay tile at the right.

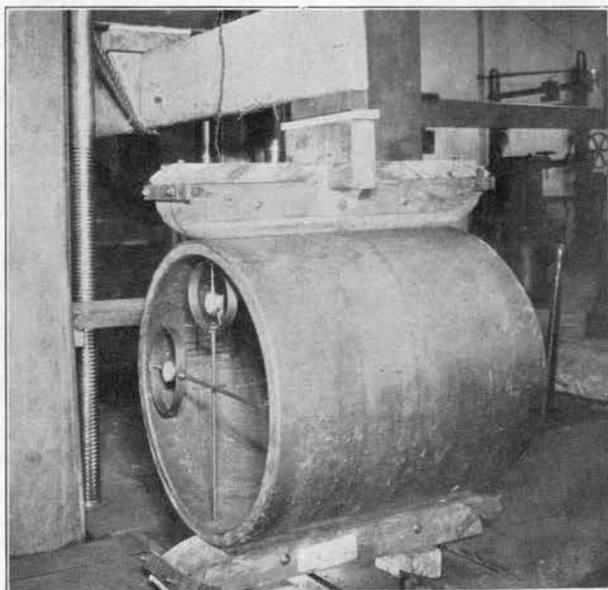


Fig. 16. The "hydraulic" method of testing drain tile. Note that both the upper and lower bearings against the tile are short sections of hose partly filled with water. Photo loaned by Mr. Mont Schuyler of St. Louis.

the large drainage sections of the Willamette and other valleys of western Oregon, than in certain portions of eastern Oregon and other parts of the country where during the winter months the ground freezes to some depth.

ABSORPTION TEST OF DRAIN TILE

In use the walls of drain tile are almost constantly in contact with moisture from both the interior and the outside. They will absorb much or little according to the amount and character of the pore space in the material of the walls. The absorption test merely determines just what amount of water the material in different tile will take up. It is made by allowing pieces of the broken tile to absorb as much water as they will, ascertaining the amount by weighing the pieces dry and after absorption.

The value of this test is very great, inasmuch as access of water to the interior portions of the tile walls may have much to do with its durability in the ground. It is pretty thoroughly established that both clay and concrete tile are not capable of bearing as heavy loads of earth when saturated as when dry. As far as the few tests that have been made to determine this point show, the difference is greater in the case of concrete than of clay tile. In regions of frigid winter weather the disintegrating effect of frost upon a tile in the ground is in general apt to be about in proportion to the amount of water it has absorbed. Soil waters of varying character that come in contact with the tile, and tend to pass into its walls, will exercise in the shell itself whatever chemical or physical alterations they are capable of in proportion to the readiness with which they can enter.

In most farming regions the nature of the soil moisture is not known to ordinarily be such as to appreciably affect the integrity of the material in the tile merely by coming in contact with its two surfaces. Many soil waters apparently produce no ill effects by passing freely through the tile walls. In the case of some clay tile, however, that are not properly burned or made of poor raw materials, or both, and of concrete tile not thoroughly cured or correctly made, especially when the latter are to be used in semi-arid regions where the drainage waters carry dissolved alkaline salts, the absorptive action may at times determine the life of the tile.

Low absorption is, in all instances, desirable, the less the better.

Water should not be expected to pass into the tile walls to any extent. The water that the tile is to drain away does not enter through its walls no matter how porous they are, but comes in between the ends of the individual tile and there only. An absolutely non-porous tile performs its function just as efficiently as the porous one with the chance that it will last very much longer if used under unfavorable circumstances. For this reason and in spite of the fact that many drain tile are being successfully used in farming regions everywhere that are classed as porous, makers should always have before them the ideal of low porosity and low absorptive power. Effort should be made to produce hard-burned clay tile and dense close-textured, properly cured concrete tile, with the knowledge that they without question will endure, while doubt as to the durability of the less well-made article will always linger.

The absorption tests of Oregon tile were made on a piece from each tile broken in the crushing test. The pieces were selected so that each would be the full thickness of the tile wall. They were thoroughly dried in an oven to constant weight at a temperature above boiling, weighed, then immersed in water and boiled for four hours. At the end of this period the pieces were re-weighed after carefully drying the surface of each specimen. The difference between the wet and dry weights is the amount of water absorbed. Weight of water expressed as a percentage of the dry weight of the

TABLE IV. TESTS OF CLAY DRAIN TILE MADE IN OREGON

Test No.	Breaking strength in lbs. per foot of length		Modulus of rupture of tile walls in lbs. per sq. in. Calculated		Percentage absorption of water		Remarks
	4-inch tile	6-inch tile	4-inch tile	6-inch tile	4-inch tile	6-inch tile	
1	815	967	1,060	1,057	10.2	8.4	
2	765	473	538	465	13.9	15.8	
4	430	514	436	370	11.8	13.5	Only 4-6-inch tile tested
12	600	629	690	582	14.9	15.0	Only 4-6-inch tile tested
13	1,210	906	942	818	14.6	14.7	
14	1,738	1,575	1,272	1,224	10.2	7.1	
19	1,113	960	808	653	11.6	11.4	
20	727	498	594	499	12.2	13.7	
21	805	746	605	777	12.9	13.4	
29	711	1,317	815	940	15.6	15.1	
30	636	424	890	565	16.6	18.4	Tile checked or cracked Only 4-6-inch tile tested

test piece is called the 'percentage of absorption' in tables iv and v. The figures for absorption, as also those in the other columns are, in each instance, the average of the results on five separate tile, except where noted otherwise under "Remarks."

TABLE V. TESTS OF CONCRETE DRAIN TILE MADE IN OREGON

Test No.	Breaking strength in lbs. per foot of length		Modulus of rupture of tile walls in lbs. per sq. in. Calculated		Percentage absorption of water		Remarks
	4-inch tile	6-inch tile	4-inch tile	6-inch tile	4-inch tile	6-inch tile	
1	687	487	817	600	9.6	11.5	Three 6-inch and four 4-inch tile tested. Others broken in ship- ping
2	993	844	1,080	1,084	9.2	9.5	
3	900	688	1,064	992	7.8	9.6	
4	874	582	953	740	10.5	11.5	
5	1,020 (8")	940	1,210	1,061	9.4	7.8	Four 8-inch instead of 4-inch tile tested

THE TILE TESTED

Following are the manufacturers from whom tile for testing were obtained.

Clay tile:

Pacific Face Brick Company, Willamina
Columbia Brick Works, Portland
Standard Brick & Tile Company, Portland
Salem Tile & Mercantile Company, Salem
Dallas Brick & Tile Company, Dallas
George F. Shew, Monmouth
Jacksonville Brick & Tile Company, Jacksonville
Hoskins & Desart, Donald
McMinnville Brick & Tile Company, McMinnville
Corvallis Brick & Tile Works, Corvallis
Tillamook Clay Works, Tillamook

Concrete tile:

Oregon Cement Sewer Pipe and Tile Company, Grants Pass
Eugene Concrete Works, Eugene
Linn Tile & Block Company, Albany
C. H. Bullen, Portland
Salem Sewer Pipe Company, Salem

Individual reports of tests have been furnished to each of the above firms. By consulting the foregoing tables (iv, v) of results each manufacturer can observe how the tests of his product compare with the others listed.

Clay drain tile are practically all made on an auger machine, a special tile die being attached to the same machine used for stiff-mud brick manufacture. Clays suitable for brick are not, however, always satisfactory for tile. Some brick clays will not run through a tile die, others laminate so badly as to produce a shelly structure in the tile walls. Concrete tile are made in molds, the smaller sizes almost entirely by machine methods. The ingredients are Portland cement and sand, or sand and crushed rock or gravel. Of the five manufacturers of the Oregon concrete tile tested, two are known to use a mixture of crushed rock and sand, and one only sand and cement. The tile are properly cured by frequent wetting for several days after they are made.

DISCUSSION OF RESULTS

Examination of the tables of results will show that the breaking strengths of the 4 and 6-inch tile differ somewhat, that of the larger tile being generally slightly less than for the small tile. The reverse is what should be expected. The thickness of the tile walls largely determines the increase of strength as the size grows larger. In general, the modulus of rupture rises with crushing strength in the case of both concrete and clay tile, the actual values being in instances equal to or greater than the supporting strength. The concrete tile group does not show as wide a variation in crushing strength as do the clay tile.

In percentage absorption of water the very lowest figure applies to 6-inch clay tile. It is notable, however, that for the group of concrete tile tested the water absorption is prevailingly less than for any equal number of clay tile in the series. As a rule, absorption varies with the breaking strength, the stronger tile being in the majority of cases the less porous. In the diagram on page 47 this relationship is brought out by plotting the strength figures in the order of absorptive power. The concrete tile show the more uniform curve, the 6-inch size running uniformly down in strength with increase of absorption. The curves for both sizes of clay tile are more irregular, though their prevailing direction tends to bring out clearly the influence of porosity, as indicated by water absorption, upon the ability of these tile to resist crushing weights.

Following is a table compiled from the report of the committee of the American Society for Testing Materials on standard specifications for drain tile.*

*Year Book, 1914, p. 331.

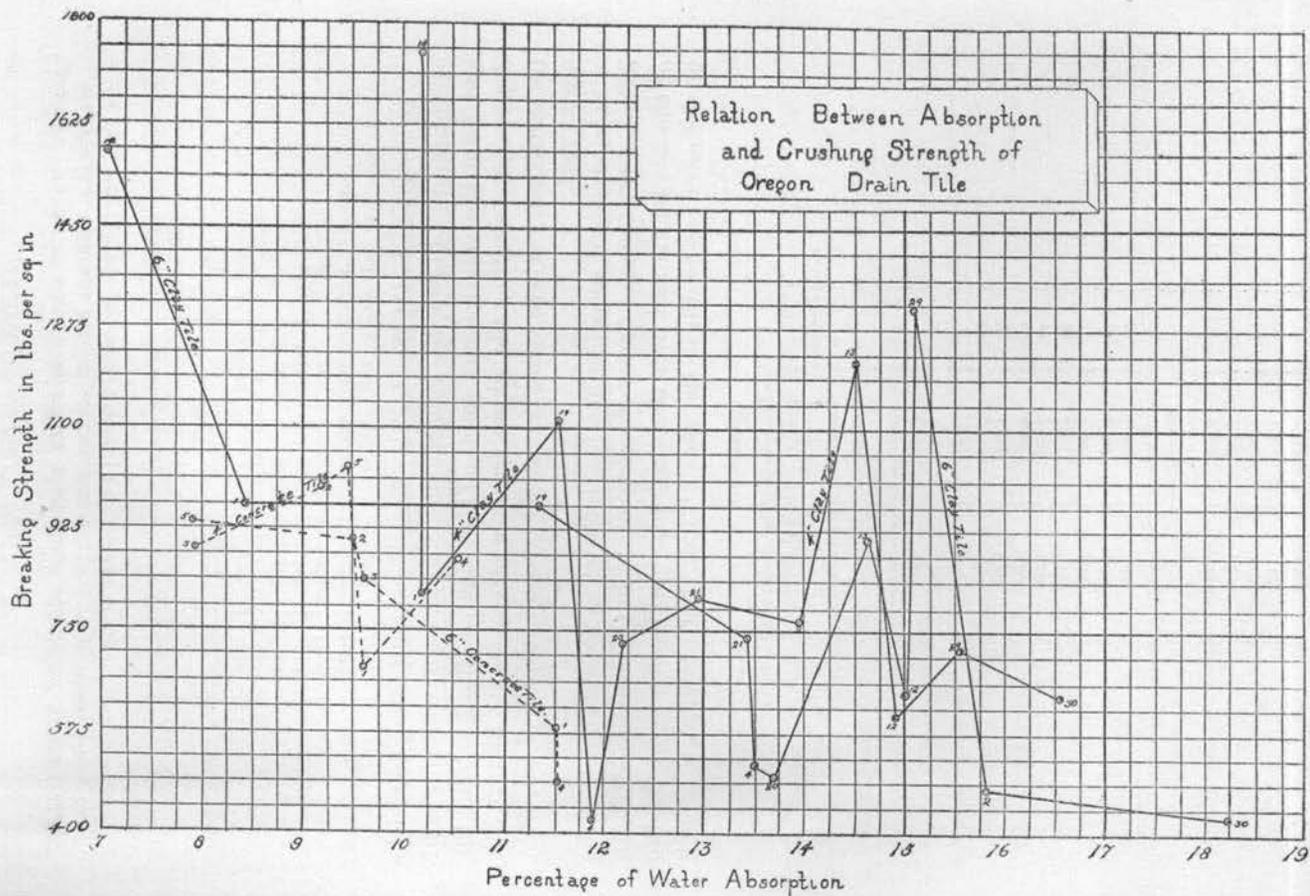


TABLE VI. MAXIMUM LOADS ON DRAIN TILE FROM ORDINARY DITCH-FILLING MATERIALS—ORDINARY SAND, 120 LBS. PER CU. FT.; THOROUGHLY WET CLAY, 120 LBS. PER CU. FT. LOAD IN POUNDS PER LINEAL FOOT.

Height of fill above top of tile feet	Breadth of ditch a little below top of tile			
	1 foot		2 feet	
	Sand	Clay	Sand	Clay
2	180	190	410	420
4	270	300	710	750
6	310	360	910	1,000
8	340	400	1,070	1,190
10	350	420	1,180	1,330

It is recommended that for clay and all common filling materials except sand and loam, the values under clay be used, while for sand and loam the values under sand. These figures afford a basis for determining whether tile whose crushing strengths are known will be satisfactory where character of the ground, depth of fill, etc., are known.

The standard specifications just referred to recommend that for ordinary tile laying a factor of safety of $1\frac{1}{2}$ in the average strength of the tile be allowed over the weight that will come upon the tile in the ditch, as shown in the above table. For example, a 12-inch

TABLE VII

Test No.	Ordinary supporting strength in pounds per foot of length	
	4-inch tile	6-inch tile
	Clay tile	
1	1,228	1,450
2	1,148	725
4	645	771
12	900	944
13	1,815	1,359
14	2,607	2,363
19	1,670	1,440
20	1,091	747
21	1,208	1,197
29	1,066	1,925
30	954	644
Concrete tile		
1	1,031	730
2	1,490	1,266
3	1,350	1,032
4	1,311	873
5	1,410 (8")	1,530

tile laid in a ditch through clay, 1 foot wide and 4 feet deep should, according to this rule, possess a supporting strength of $1\frac{1}{2}$ times 300 or 450 pounds to be safe; laid in a ditch 2 feet wide and 6 feet deep, 1,000 pounds, etc.

The so-called "ordinary supporting strength" is obtained from the breaking strengths given in the tables of tests by multiplying each result by the factor 1.5. Table VII gives the ordinary supporting strengths of Oregon drain tile. The figures in this table should be used in comparing with the values in table VI.

CONCLUSIONS

A general survey of the results of the Oregon tile tests, along with a knowledge of the character and appearance of the individual tile, warrant the statement that the majority of them are sufficiently strong to safely bear any ordinary weights of filling. Those about which there might be some question on this point are pretty generally indicated in the tables by the lowest crushing strengths. In the case of a few of them, tile were found to be broken in shipping, even though they were properly crated and had apparently been well packed at the start. Other evidences of weakness were observed in the lack of uniform texture, roughness, or, when broken, a shelly or otherwise incoherent structure. In most instances where such defects were noted, there was also evidence that they were the result of the way in which the tile were made and, therefore, susceptible of correction and improvement.

It is to be recalled that only small tile, 6-inch and 4-inch were tested. It should be realized that the strength tests of these small sizes is a much less important one than in the case of larger tile. It is very rare that such small tile will be found lacking in initial strength when they are in other respects acceptable. Water absorption, however, as giving a clue to the hardness and density of the tile structure is fully as important with small as with the larger sizes of drain tile for the reasons mentioned in the discussion of absorption on a previous page. Low porosity and low absorption go with greater strength as a rule and are a factor largely under the control of the manufacturer of either the clay or the concrete drain tile.

The standard specifications for drain tile stipulates that "tile shall be reasonably smooth on the inside, and free from cracks and checks extending into the body of the tile in such a manner as to appreciably decrease the strength. Tile stood on end and tapped with a light hammer when dry shall give a clear ring. Tile shall

be free from chips or broken pieces which will decrease strength or admit earth into the drain. The end shall be regular and smooth and admit of the making of a close joint when properly turned and pressed together." These statements apply to both concrete and clay tile and refer to conditions only that every progressive manufacturer of tile should and would have constantly in mind without the intervention of a 'standard specification' or formal requirement calling his attention specifically to them.

TESTS OF OREGON HOLLOW CLAY BLOCKS

The most common use to which the hollow clay block or building tile is put is for interior partitions. A certain type of block is thus known as the "partition tile." As their advantages become known, more of the blocks are being used, however, for the construction of the exterior walls of buildings in place of brick or other materials. These advantages are frequently given as (a) lighter weight per cubic foot of wall; (b) sufficient strength to insure a large factor of safety; (c) much less clay required; (d) lower transportation costs for a given bulk; (e) full protection against dampness and temperature; (f) fire-resisting properties; (g) deadening against transmission of sounds; (h) less labor required to lay in the wall.

In an exterior wall, hollow blocks must meet and fulfill the same conditions as to strength and absorption as do brick. For interior partitions strength qualities are of less importance, and the blocks are customarily made somewhat porous and soft so they may be cut and so add to their fire-resisting properties. Blocks are made in a large variety of sizes according to their particular use, and of plastic clays that will run satisfactorily through a block die on an auger machine.

The following Oregon factories kindly furnished samples of their product for testing.

Columbia Brick Works, Portland
Standard Brick & Tile Company, Portland
Salem Tile & Mercantile Company, Salem

Very few systematic tests of hollow clay blocks have been made elsewhere. The results of the tests of the Oregon blocks are arranged in the accompanying table VIII.

Before being placed in the testing machine both the upper and lower surfaces of each block were coated with a thin layer of plaster of Paris so as to insure an even bearing. All blocks tested were made with two webs or partitions trying the walls, as shown in

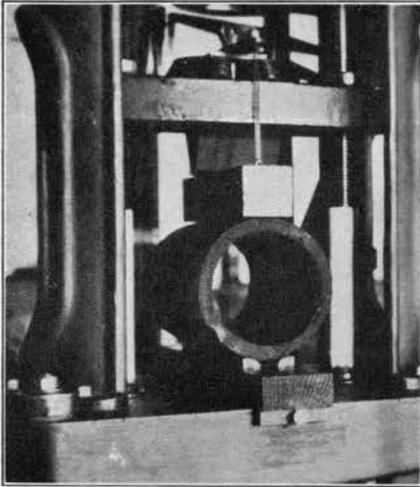


Fig. 17. Drain tile in position for crushing test. Three-point method.

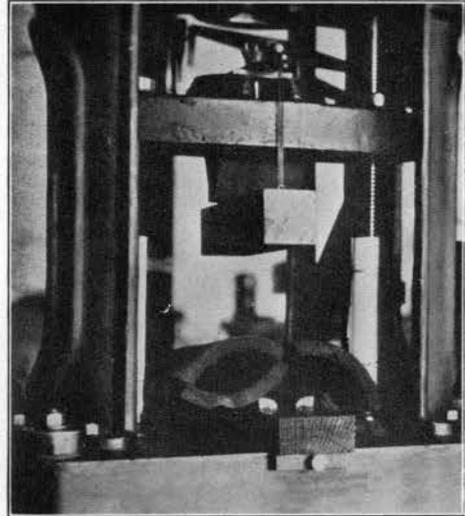


Fig. 18. Showing characteristic collapse of tile in crushing test. Tile usually breaks lengthwise at top, bottom and 90-degree points.

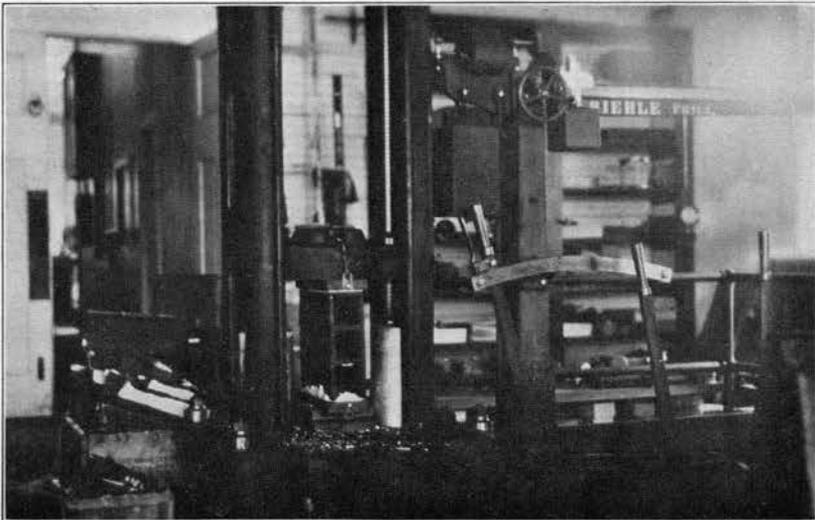


Fig. 20. Hollow clay block in position for making crushing test. The block is bedded in plaster both above and below and is crushed edgewise, its position in a wall, the pressure being applied perpendicular to the partition webs.

TABLE VIII. TESTS OF CLAY BUILDING BLOCKS

No. of test	No. of blocks tested	Nominal dimensions of block	Thick-ness of wall— inches	Breaking load, lbs. per sq. in.		Per-centage of absorp-tion	Remarks
				First crack	Fail-ure		
2	A....	12 x 12 x 4	.8	368	730	16.7	Warped and checked in one side. In crushing test side first broke away from web
	B....	12 x 12 x 4	.81	238	522	15.2	
4	C....	12 x 12 x 4	.8	80	370	14.7	Broke suddenly First crack across bottom First crack center partitions pulled loose
	A....	12 x 12 x 4	.77	471	474	16.7	
	B....	12 x 12 x 4	.84	342	410	17.5	
	C....	12 x 12 x 4	.77	241	340	17.7	
12	D....	12 x 12 x 4	.76	365	605	16.2	Slightly checked—first crack webs pulled loose
	A....	12 x 12 x 4	.63	253	315	15.8	
	B....	12 x 12 x 4	.61	137	288	16.3	
	C....	12 x 12 x 4	.63	57	309	16.5	
	D....	12 x 12 x 3	.61	345	790	13.4	
	E....	12 x 12 x 3	.61	159	551	14.2	
25	F....	12 x 12 x 3	.62	212	545	13.6	First failure in corners First failure in flat top First failure in corners First failure in corners
	A....	12 x 6 x 8	.77	123	327	20.1	
	B....	12 x 6 x 8	.75	154	366	20.1	
	C....	12 x 6 x 8	.76	82	376	19.6	
	D....	12 x 6 x 8	.74	177	502	16.8	

figure 20. Each was placed in the testing machine in the position it would occupy when laid in a wall. Nos. 2, 4 and 12 were crushed on edge, that is, with the pressure plates parallel to the webs, the compression applied, therefore, at right angles to them. Blocks No. 25 were broken flatwise by applying pressure in a direction parallel to the dividing webs. In the first case failure usually began by the side-walls breaking away from the webs, the tendency being to produce a tension in the latter. In testing No. 25 the webs were in compression edgewise, the first evidences of failure usually appearing at the corners of the block.

LIMESTONE DEPOSITS IN OREGON

BY IRA A. WILLIAMS.

THE LIMESTONE PROBLEM

Great importance attaches at present to determining the location and availability of the limestone resources of the state, particularly on account of the rapidly growing demand for limestone to apply to acid agricultural soils and for use in the manufacture of Portland cement. Its need for the treatment of acid soils is most strongly felt in various parts of the most productive portions of the great Willamette valley where the farmers are beginning to realize that only this is necessary to transform their soils from a state of rather narrowly limited productivity to lands of boundless capabilities. Other farming regions will sooner or later require similar treatment. From this standpoint, therefore, this one of Oregon's mineral resources is seen to have an intimate and essential practical relationship to the development of the state's most fundamental industry, farming.

Oregon uses thousands of barrels of Portland cement annually but to date has not produced a single pound of this commodity for the market. The cement consumed here has been shipped hundreds of miles by rail from neighboring states, and from foreign countries by water. Pure lime, such as limestone affords, is an essential ingredient, along with clay or shale, in the making of Portland cement. Here again it is impossible to overlook the extreme importance of ascertaining just what Oregon possesses in the way of limestones within reasonable reach of our railroads and markets, with a view to their utilization for cement manufacture.

Along with a number of other problems, equally or comparatively important in some of the other fields of our mineral industries, the Bureau of Mines and Geology has given a great deal of attention during the entire period of its existence to searching out available limestone beds in the parts of the state contiguous to transportation facilities. The field parties of the Bureau that have worked in various sections of Oregon during the season just closing have noted and described the limestone deposits wherever they have been found. As will be readily appreciated, however, when the vast size of the state is considered, it has not been possible in the short period of two years to make more than a small beginning

on the problems, or to cover any considerable area in sufficient detail to permit of the announcement of conclusive results.

During the season of 1914, two men were placed in the field to continue the search for limestone, particularly in certain accessible regions bordering the Willamette valley. It was intended to devote the full season to this work because of the thoroughly realized necessity of determining absolutely what are the limestone resources of this section of the state. Less time was actually given to the problem, however, than was originally contemplated, largely on account of the urgent request from Governor West for an investigation of the salines of Summer and Abert lakes in eastern Oregon. The Governor's request came to the Bureau at a time when the remaining available funds for the biennium were definitely assigned to other projects. The entire staff was likewise actively engaged in important work that was well along towards completion. In the face of these conditions the only adjustment it was possible to make in order to give proper attention to Summer and Abert lakes was to discontinue the limestone investigations.

The work on the limestone problem is one of inestimable importance, having to do, as it does, so intimately with the fertility of our agricultural soils and affecting the home production of so essential a modern building material as Portland cement. At the present moment, however, the enforced inability of the Bureau to devote a greater amount of time to the problem may be less serious, so far at any rate as the cement industry is concerned, than in a time of normal business activity. The general quiet which characterizes the expansion of business in this country just now as a result of the troublous times abroad, and the consequent cutting off of many foreign markets has brought the promotion of many enterprises to a standstill. The development of a Portland cement industry in Oregon, which depends largely upon her deposits of limestone, is thus, as are other enterprises, temporarily suspended owing to the tension of business conditions.

The officials of the Oregon Bureau of Mines and Geology keenly realize the necessity of giving to this problem the attention it deserves and of spending the requisite amount of time and money in its prosecution. At this time only a progress report of the findings of the Bureau will be made. This report will embrace a brief summary of the existing knowledge concerning the limestone deposits in Oregon, including whatever information pertaining to them the Bureau of Mines and Geology has secured during the past two years.

LIMESTONE IN SOUTHWESTERN OREGON

Jackson and Josephine counties.—The chief limestone deposits in Josephine and Jackson counties occur in four fairly well-defined belts having a general trend from southwest to northeast. They are as a rule elongated or lens-like masses, usually less than a mile in length and but a few hundred feet in thickness. The belts in which the limestone beds occur are given by J. S. Diller* as follows.

The first belt of limestone includes prominent ledges 3 miles southeast of Kerby as well as several on Cheney creek, where the conditions are favorable for handling the material and for getting it to Grants Pass by an easy haul of 12 miles.

The second belt is less regular. It extends from the vicinity of Gold Hill on the main line of the Southern Pacific Co., southwestward by the Oregon Bonanza mine to the well-known Oregon Caves, and beyond into California.

The third belt, which has several readily accessible ledges on Kane creek, appears to the southwest on Applegate river, on Steamboat creek, and in the vicinity of Whisky peak, where the belt enters California.

The fourth belt of limestone appears on Little Applegate river, and possibly also on Applegate river near Watkins, where a prominent limestone lens occurs close to the mica schist, which it appears to overlie.

The main occurrences in these four belts have been described by A. N. Winchell in the August, 1914, number of the Mineral Resources of Oregon, from which the following facts are taken. With reference to the limestones in the vicinity of the Upper Applegate and Little Applegate rivers Dr. Winchell says:

There is considerable limestone in section 19, T. 40 S., R. 4 W. about 2 miles west of Steamboat; here the strike is N. 20° E. and the dip is 85° E., but both strike and dip vary considerably in different outcrops. The limestone here occurs in masses 50 to 100 feet thick and as much as 600 feet long. Other outcrops are known near Watkins, not only along the river to the south in section 11, T. 41 S., R. 4 W., but also in Collins mountain in section 35, T. 40 S., R. 4 W. There are several limestone lenses near the Applegate river in T. 36 S., R. 4 W., and others along the Little Applegate river in T. 39 S., R. 2 W.; one of these is on 7-mile ridge about a mile and a half south of the mouth of Glade creek; another is on Yale creek in section 32, T. 39 S., R. 2 W.; other outcrops striking N. 15° E. occur on the ridge north of Little Applegate in sections 19 and 20, T. 39 S., R. 2 W.

An analysis of the limestone outcropping south of Watkins made by R. C. Wells† of the U. S. Geological Survey resulted as follows:

**COMPOSITION OF LIMESTONE FROM SECTION 7, T. 41 S., R. 4 W. ON
THE APPLGATE RIVER**

SiO ₂	0.53
Al ₂ O ₃ /	
Fe ₂ O ₃ }	.52
MgO.....	trace
CaO.....	55.05
H ₂ O.....	.50
CO ₂	43.25
	99.85

*Bull. U. S. G. S. 546 p. 15. 1914.

†U. S. Geological Survey Bulletin 380, p. 51, 1909.

As to limestone in the Gold Hill district Winchell states (p. 158):

The chief limestone lenses of the Gold Hill district are as follows:

On Kane creek in section 11, T. 37 S., R. 3 W., a limestone lens of unusually large size, or perhaps two or more lenses, extend from north to south across the section with a measured thickness varying from 200 to 300 feet. The enclosing rocks are slates or argillites, though the Siskiyou granitic batholith approaches within 100 feet of the limestone in one place. The sedimentary rocks strike N. 10°-17° E. and dip 80°-85° E. A smaller lens of limestone less than half a mile to the northwest in Sec. 2 is the site of lime quarries owned by Hughes and Householder. Here the limestone is probably more than 100 feet thick and has the same strike and dip as in the preceding outcrops.

Near Gold Hill in section 16, T. 36 S., R. 3 W., a limestone lens has a thickness of 50 to 100 feet and a length of at least 1000 feet; it strikes about N. 20° E. and dips about 65°-80° E. It is interbedded with argillaceous shales. At this location the Beaver Portland Cement Company is erecting a cement plant having a capacity of 1000 barrels a day.

On Galls creek in section 21, T. 36 S., R. 3 W., at an elevation of about 1300 feet above sea level limestone outcrops, but the extent of the deposit is unknown. It seems to be of good quality. On the west side of Galls creek near the south side of section 20 at an elevation of about 1400 feet a lens of limestone has a thickness of about 200 and a length of at least 500 feet. It strikes about N. 10° E. and dips about 85° E. To the southwest a few hundred feet two more lenses of limestone are found parallel to the first and separated by quartzite.

On Wilson creek in section 30, T. 36 S., R. 3 W., a conspicuous, white ridge-like outcrop consists of limestone and white quartzite. It is about 300 feet wide and a quarter of a mile long and rudely lenticular. The strike is N. 30° E. and the dip is nearly vertical.

On Rogue river in the S. E. $\frac{1}{4}$ of Sec. 23, T. 36 S., R. 4 W., about two miles west of Rock Point at an elevation varying from 1500 to 1900 feet, a lens of limestone about 100 feet thick strikes N. 35° E. and dips about 70° S. E. This is on land owned by M. S. Johnson, of Gold Hill.

There are undoubtedly still other lenses of limestone in this district, but they are probably less accessible than the deposits described.

Numerous analyses have been made to show that these limestones are suitable for use in making cement. There is little doubt that by suitably mixing them with shale or clay of the region a good cement can be made, perhaps by the use of coal obtained in the Rogue river valley. The following analyses are of importance in this connection.

COMPOSITION OF LIMESTONES NEAR GOLD HILL

	A	B	C	D	E	F
SiO ₂.....	.31	.37	25.21	.92	23.86	3.1
Al ₂ O ₃ +Fe ₂ O ₃.....	.44	.20	.....	.....	.32	2.2
MgO.....	.03	.01	.62	.40	trace	2.5
CaO.....	55.34	55.71	39.02	55.00	41.83	50.0
H ₂ O.....	.56	.37	.....	.....	.46	.....
CO ₂	43.23	43.54	31.48	43.66	32.57	42.2
	99.91	100.20	96.33	99.98	99.04	100.0

A. Householder's quarry on Kane creek in sec. 2, T. 37 S., R. 3 W.

B. Hughes' (Carter's) quarry on Kane creek in sec. 2, T. 37 S., R. 3 W.

C. $\frac{1}{2}$ mile west of Gold Hill in sec. 16, T. 36 S., R. 3 W.

D. 1 mile northwest of Gold Hill in sec. 16, T. 36 S., R. 3 W.

E. $1\frac{1}{2}$ miles southwest of Gold Hill in sec. 20, T. 36 S., R. 3 W.

F. Near Rock Point, probably in sec. 23, T. 36 S., R. 3 W.

(Analyses A, B, and E made by R. C. Wells, U. S. Geol. Survey Bulletin 419, p. 209. Analyses C and D made by P. H. Bates, U. S. Geol. Survey Bulletin 387, p. 29. Analysis F. made by J. S. Phillips, U. S. Geol. Survey Bulletin 387, p. 29.)

Along the Lower Applegate river a bed of marble has been exploited at a point four miles west of Williams. Marble is a metamorphosed and usually crystalline limestone, not differing from the latter in composition. It may thus serve for practically any purpose that limestone is suitable, besides its many possibilities for interior decorative and sanitary uses. Winchell thus describes the marble near Williams, as it may be seen in what is known as the Jones quarry, the town being in Josephine, but the marble in Jackson county (p. 232).

It is in section 31, T. 38 S., R. 5 W., at an elevation of about 2650 feet, as measured by barometer. The limestone here strikes N. 45° E. and dips about 65° S. E. The rock is a variegated marble in this opening, being white and blue; in some places it is stained by limonite derived from the alteration of pyrite. The marble forms a lens which is about 2000 feet long and about 300 feet wide as a maximum. At the northeast end it is cut off abruptly; at the southwest end it tapers to a point. It forms a cliff on the side away from the dip, that is, on the northwest side. It contains argillaceous streaks and "knots" in some places. It is said to be on railroad land.

This deposit has been used under very unfavorable conditions. It is about an eighth of a mile from the nearest wagon road, and about 6 miles from the place where the stone cutting and polishing have been done. Naturally, the results have not been satisfactory, although the stone is of good quality.

An analysis of this marble made by R. C. Wells* of the U. S. Geological Survey resulted as follows:

COMPOSITION OF MARBLE NEAR WILLIAMS

SiO ₂.....	.13
Al ₂ O ₃} } .....	.38
Fe ₂ O ₃ }	
MgO.....	none
CaO.....	55.55
H ₂ O.....	.26
CO ₂	43.63

99.95

The analysis shows that the marble is over 99 per cent pure calcite.

There are other limestone deposits farther down the Applegate river towards its confluence with the Rogue on Williams, Oscar and Cheney creeks.

On the land of the Rogue River Lime Company in the S. W. ¼ Sec. 19, T. 37 S., R. 6 W., limestone forms a cliff the base of which is at an elevation of 2,660 feet, as measured by barometer; near the southern end of the limestone outcrop about 2000 feet from the cliff the elevation is 3060 feet. The outcrop of limestone has a rudely lenticular outline with a blunt end at the southwest, being 120 feet wide within 100 feet of the end and 400 feet wide about 500 feet northeast of the end. About 1200 feet from the end the limestone is about 600 feet wide. At the northeast end the limestone terminates in a sharper point being about 50 feet wide within a short distance of the end. At about 150 feet from this end, along the trail, 30 feet of sandy shale lie between 50 and 100 feet of limestone. Measured across the strike the last distance would probably be about 100 feet.

*U. S. Geol. Survey Bulletin 419, p. 209. 1910.

The limestone deposit as a whole consists of two lenses, or a compound lens, separated by 30 feet of sandy shale. It strikes to the northeast and dips to the southeast. Analyses of the limestone follow which show that the deposit is remarkably pure and well suited for use with suitable shale in the manufacture of Portland cement.

COMPOSITION OF LIMESTONE ON CHENEY CREEK

	A	B	C	D
SiO ₂.....	.23	} .2	.4	2.1
Al ₂ O ₃ +Fe ₂ O ₃.....	.28			1.2
MgO.....	.03	.1	.4	trace
CaO.....	55.28	55.6	55.3	54.3
H ₂ O.....	.50			
CO ₂	43.57	43.8	43.7	42.6
	99.89	99.7	99.8	100.2

A. Rogue River Lime Co. quarry on Cheney creek in section 19, T. 37 S., R. 6 W.
 B. Face of cliff in section 19, T. 37 S., R. 6 W.
 C. Croppings in section 19, T. 37 S., R. 6 W.
 D. Stripping in section 19, T. 37 S., R. 6 W.
 (Analysis A made by R. C. Wells, U. S. Geological Survey Bulletin 419, p. 209. Analyses B, C, and D made for the Rogue River Lime Company and reported by S. B. Gorbutt of Grants Pass.)

Over the divide to the southwest in the west quarter of section 30, T. 37 S., R. 6 W., there are two more outcrops of limestone, one in the form of a cliff at least 100 feet in height. This has been opened in a small way by Mr. Sorenson of Portland; it is also claimed by Conger & Co. This limestone also strikes about N. 45° E. with a steep dip to the southeast. So far as visible on the surface the outcrops in section 30 are much smaller than that already described in section 19. They seem to be portions of the lens in section 19 cut off its southern end and displaced to the south by a fault striking nearly north.

A somewhat important limestone deposit exists on Elder creek, one of the head waters of the Illinois river, in Josephine county. It is near the town of Takilma, is accessible and was used as a source of lime flux when smelting was being done at this point. Quoting again from Winchell, p. 243.

Another deposit, located 3 miles S. 70° E. of Kerby, is known to be very pure calcium carbonate.

Several other outcrops of limestone are known in the central and eastern parts of the Waldo district. Thus there is a small exposure on Sucker creek between Grizzly gulch and Limestone creek, and outcrops are reported near Swan mountain and on the west flank of Whiskey peak, but the largest and most interesting occurrence is on and near Cave creek. Here the limestone is remarkable for its extensive caves, and the Federal Government has set apart three fourths of a square mile as a national "monument." Thus, the caves will be protected and preserved for the benefit of the people for an indefinite period. This limestone is not available for commercial purposes because of its reservation as a national "monument."

From this brief reference to the limestone deposits known to exist within examined portions of Jackson and Josephine counties, it is seen that there are vast quantities of good stone available largely within the watershed of the Rogue river, some of which is now within reach of transportation, therefore development. Many

beds of usable quality are likewise now remote, but these are properly to be regarded as a valuable potential resource merely awaiting the course of development which the future of this section of Oregon has every reason to expect.

Curry county.—Rumors have come to the Bureau of important deposits of limestone in Curry county. No information has been obtained to confirm or deny the truth of these rumors. The resources of Curry county should be given attention at an early date.

Coos county.—Reports are also received of limestone at points in the vicinity of Coos Bay. Several years ago traces of limestone were found in this section by the U. S. Geological Survey as reported in folio 73 of that survey. Quoting from page 2 of the above mentioned folio:

Traces of limestone have been found at a number of places within the Coos Bay quadrangle, but the masses are too small to be indicated on the map. They are of scarcely any economic importance. On the east fork of the Kentuck Slough in Sec. 3, Tp. 25 S., R. 12 W., several boulders of limestone were observed. The rock is composed almost wholly of microscopic fossils of many varieties. On Denton creek in Sec. 13, Tp. 25 S., R. 12 W., and also Sec. 27, Tp. 25 S., R. 12 W. one-fourth of a mile southwest of the forks of Coos River there are similar rocks full of minute fossils, which, according to Dr. G. H. Girty, are calcareous algae and foraminifera of marine origin. On Daniels creek near its mouth concretions of limestone occur in Pulaski shales. No traces of fossils have been found at that point. The nodules are so abundant that some years ago they were burned to furnish the lime used in constructing a neighboring building. All of the outcrops of limestone are close to the diabase and in some cases contain lapilli, suggesting that the eruption of the igneous material was submarine.

Recently Mr. F. C. Wood sent to the Bureau a sample of fairly pure limestone from this region. Mr. A. J. Collier of the Bureau reported as follows after examining the deposit from which this sample was obtained.

The point visited is situated in the northeast fourth of Sec. 36, T. 25 S., R. 12 W. about three hundred feet above the (Coos) river. The exposure is in a small stream and appears to be a very irregular mass of limestone and shale. Its vertical dimension is approximately fifteen feet; its lateral extent could not be determined though at one time a similar deposit had been opened up at about the same elevation on one-fourth of a mile south.

The limestone bed represented was deposited in the upper part of the basalt mass and cannot be expected to have a uniform thickness. There is no doubt that samples showing eighty-five per cent calcium carbonate can be obtained from the purer parts of the deposit. In approaching this location Mr. Brusckie pointed out the fact that the basalt rocks often have calcite amygdulites sufficiently abundant to make the rock yield thirty per cent of lime.

Douglas county.—In Douglas county lens-shaped masses of limestone occur in the sandstones and shales south and southeast of Roseburg at intervals along the ridge and slopes extending northeast from the Umpqua river nearly to the head of the north fork of Deer creek. The following general description of these exposures

and of others in this county is taken from Bull. 387 of the U. S. Geological Survey, p. 32.

The limestone is a massive gray rock, and as it has yielded satisfactory lime in several localities it is probably of good quality. The southwesternmost occurrence is in sec. 30, T. 28 N., R. 5 W., near the top of a prominent ridge; the rock is traceable for only about 100 yards, with a width of 30 to 40 feet, so the supply is not great. The next exposure, a mile northeast, in secs. 20 and 29, shows a much larger body of limestone rising in prominent ledges with the beds dipping northwest at an angle of 70°. The next body, which is mostly in sec. 14 of the same township, is somewhat smaller, but shows a thickness of 60 feet. Two small bodies occur on the south and north forks of Deer Creek in the next township northeast (T. 29 N., R. 4 W.); they are so compact that they are regarded as marble and have been quarried to some extent for that material. The last mass to the northeast is only 15 feet thick.

Near Oakland there are three small masses of impure limestone which have been regarded as cement rock. One is by the road nearly a mile northeast of Oakland, another at the head of Green valley, 6 miles northwest of Oakland, and the third on Starr's ranch about 4 miles northeast of Umpqua ferry. The areas are less than an acre in extent. Near Oakland the rock is a bluish shaly limestone that falls to pieces rather readily on exposure. It contains, besides a few fossils, brownish veins and nodules of various sizes up to 4 feet in diameter. At Starr's ranch the limestone is full of broken shells and the beds dip gently to the northwest.

One of these limestone masses located $3\frac{1}{2}$ miles from Green's station below Roseburg on the Southern Pacific railroad has been thoroughly investigated by the Portland Cement Company of Oswego, Oregon. The following statements relating to this limestone are quoted from the report of R. K. Meade as given in the prospectus of the above named company.

Beginning at the foot of a hill the stone outcrops boldly and these outcrops extend in a northeast direction to the brow of the hill, which is quite high. The outcrops are from 50 to 75 feet thick. On the north side of the hill, about 100 feet from the top, are also some exposures. The top of the hill has not been explored, but the drift suggests sandstone. There are a great many boulders below the limestone outcrops that have been broken off from these latter. These boulders are likely to mislead the inexperienced and to create the impression that the limestone deposit is much thicker than it really is. The deposit is in the form of a narrow lentil and runs for at least 1500 feet around the brow of the hill, which is probably from 500 to 600 feet high. The strike is from southwest to northeast and the inclination is about 70 degrees. That is, the beds are practically on edge.

Chemical Composition: Two samples were taken from the outcrops of this limestone. One at the foot of the hill where a small quarry had been opened, and one from the outcrops near the top of the hill. These analyses follow:

ANALYSES OF SAMPLES FROM ROSEBURG, OREGON

Sample	Silica	Iron oxide and alumina	Carbonate of lime	Carbonate of magnesia
Chipped from outcrops near top of hill.....	1.84	1.44	96.27	1.14
Chipped from outcrops at foot of hill and from old quarry.....	1.20	0.90	97.51	0.79

The above show the limestone to be very pure—high in carbonate of lime and very low in magnesia, silica, oxide of iron and alumina. It is suitable in every way for the manufacture of Portland cement, either by mixing with a suitable shale or the low grade limestone found at Dallas. Physically, the limestone is massive but not particularly hard* * *. The quantity available if quarried to its full depth is not less than 8,000,000 tons.

From time to time samples of limestone have been received from the vicinity of Drain and rumors have come regarding its occurrence in that region and in the vicinity of Riddle, both in Douglas county. The source of the samples has not been ascertained nor the rumors confirmed. Here is a large area, however, traversed by the Southern Pacific railway that is worthy of detailed examination as soon as that work can be done.

LIMESTONE IN NORTHWESTERN OREGON

For several years, effort has been put forth by many persons and corporations to find limestone of high grade within the limits of the watershed of the Willamette river. These efforts have resulted in the location of several impure deposits within the borders of the valley and the accumulation of considerable knowledge regarding their extent and character. Beyond the boundaries of the valley proper, however, only a desultory search had, prior to 1914, been made in the foot-hills of the Cascades and of the Coast range. On the Pacific slope also, even in the settled portions, practically no systematic work had been done to ascertain the possible existence of workable beds of limestone. As heretofore stated, some time was put upon this particular problem during both 1913 and 1914 by the Bureau of Mines and Geology. Following is a summarized review of present knowledge concerning limestone in this part of the state drawn from various published sources and from the results of the Bureau investigations of the past two seasons.

Upper Willamette valley.—An amygdaloidal lava exposed in the southwestern part of the city of Eugene (T. 18. S., R. 4 W., Sec. 1) contains in places from 10 to 50 per cent of lime carbonate that has crystallized in the cavities of the rock. It is understood that a few loads of the sorted calcite crystals have been burned in Eugene for lime. The rock is not rich enough in lime to be used for cement manufacture nor for application to land except possibly in small quantities and locally.

A careful reconnaissance along the Willamette Pacific railroad's new line from Eugene to the coast, by A. J. Collier for the Bureau revealed no workable limestone deposits whatever. A similar

examination of the formations exposed along the McKenzie river and its branches contiguous to the main valley by G. J. Mitchell disclosed no beds of limestone. The rocks here, from Springfield to the source of the McKenzie in the high Cascades, are prevailingly igneous with occasional conglomerates, tuffs and sandstones appearing.

Lower Willamette valley.—In the lower part of the valley impure limestone is known to exist in quantity in at least two localities, near Dallas in Polk county and near the town of Marquam in Clackamas county. The following statements by H. M. Parks with reference to the Dallas stone appear in the Feb. 1914 issue of the Mineral Resources of Oregon, p. 36.

The quarries in this stone are situated in sections 11 and 12, T. 8 S., R. 6 W., about 4 miles southwest of Dallas. The Falls City branch of the Salem, Falls City & Western railroad runs about one mile south of the quarries. A railroad grade has been built to them.

The stone consists of a series of flat lying beds. In one of the pits the observed strike was due north and south and the dip 7° E. The beds average about 10 feet in thickness and are separated by a thin strata of shaly material.

The Dallas deposit is at present owned by the Portland Cement Company of Oswego. From the prospectus of this company the following statements are taken from a report on the property by Richard K. Meade, C. E.

Extent and Character of the Deposit: The deposit itself appears to consist of a rather wide lens, the strike of which is from southeast to northwest. The lens covers all of one hill and part of another, the two hills being separated by a small gulch. The strike of the deposit apparently runs at right angles to the main ridge. There is probably another lens to the west of the main body, but no holes have been drilled in this* * *. It is safe to say that the main lens is at least from 1000 to 1500 feet wide and probably much wider, and that there is available certainly not less than 11,000,000 tons of limestone and very likely much more. Part of this is unsuited to the manufacture of Portland cement, owing to improper proportions between the various constituents, too small a percentage of carbonate of lime, etc., but there is certainly a considerable body of limestone here suitable for the manufacture of a high grade Portland cement.

This stone is so situated that quarrying can be carried on most economically. Operations can be commenced near the foot of the hill and the quarry pushed back to the level. This would soon result in an extensive face of rock and consequently minimum cost of getting out the rock.

Chemical Characteristics of the Limestone: I brought back with me nine samples from this property. These I have carefully analyzed. A description of the samples and my analyses follow:

In character the rock is an argillaceous limestone of average hardness and density. As you will note, several of the samples are high in carbonate of magnesia, but as these which are highest in magnesia would have to be mixed with a large quantity of pure limestone in order to make cement from them, the quantity of magnesia contained in the stone is not too great for the manufacture of a high class Portland cement, provided some stone low in magnesia, such as that from Roseburg, is used with it. The rock is somewhat high in oxide

LIMESTONE DEPOSITS IN OREGON

ANALYSES OF SAMPLES FROM DALLAS, OREGON

Sample	Silica	Oxide of iron	Alumina	Carbonate of lime	Carbonate of magnesia
Selected samples of dark blue limestone taken from quarry at site of crusher.....	34.24	9.45	7.47	38.65	9.66
Selected sample of brown limestone taken from quarry at site of crusher.	31.86	4.75	7.69	51.68	3.33
Chipped from outcrops at extreme S. W. of Farley property.....	14.56	3.75	4.55	72.69	2.24
Chipped from face of rock in Riley quarry.....	15.38	5.70	6.58	66.49	4.28
Chipped from place from which court house stone was taken.....	18.82	4.05	4.77	67.59	3.54

RESULTS OF CORE DRILL SAMPLES

Sample	Depth	Silica	Iron oxide and alumina	Carbonate of lime	Carbonate of magnesia
Core No. 1.....	1-20 ft.	31.32	16.50	44.50	6.40
Core No. 1.....	50-60 ft.	32.64	19.24	36.44	9.58
Core No. 6.....	0-10 ft.	18.30	10.30	65.42	4.15
Core No. 8.....	30-40 ft.	33.06	14.82	45.03	5.25

of iron, but not sufficiently so to condemn it for the manufacture of Portland cement.

The main point with this material is the quantity of carbonate of lime which it contains. The top beds are much higher in carbonate of lime than the lower ones. This is shown by both my surface samples and those from the core drill. I do not believe that it will be possible to quarry the stone so that it will contain more than 55 per cent of carbonate of lime, and I think it is probable that if quarried economically it would run lower than this, or not more than 50 per cent carbonate of lime. Taking the figure of 55 per cent carbonate of lime, it would be necessary to add to this stone about an equal quantity of stone from Roseburg.

Conclusions: First, that part of the stone comprising the upper beds at Dallas is suitable for the manufacture of a high grade Portland cement, provided that there is mixed with it a sufficient limestone which is high in carbonate of lime and low in magnesia to make a mixture of the two limestones containing about 75 per cent carbonate of lime, and not more than $5\frac{1}{4}$ per cent of carbonate of magnesia.

Second, that there is at least 11,000,000 tons of limestone suitable as explained above and available on the property.

Third, that the quarrying can be economically carried out.

The Marquam limestone is thus described by S. B. Newberry on page 8 of the prospectus of the Portland Cement Company who own this deposit.

This is an impure limestone, largely composed of fossil shells, which forms the surface rock over an area a mile or more in length and varying in width, situated about a mile from Marquam, and about 6 miles east of the Southern Pacific railroad. The rock outcrops or comes close to the surface over an area of at least 100 acres.....

I have read with much interest the report of this deposit by Mr. Edwin C. Eckel..... He states that the Marquam deposit is, 'so far as known, the only workable deposit of Portland cement material in northwestern Oregon'. He gives an analysis 'of a careful average sample taken across the entire thickness near the old lime kiln' as follows:

Silica.....	14.88
Alumina.....	4.09
Iron oxide.....	1.63
Carbonate of lime.....	77.98
Carbonate of magnesia.....	1.32

99.90

As stated by Mr. Eckel, this shows an almost perfect Portland cement raw mixture and if the rock were of this composition, practically no additional material would be required. Analyses of other samples taken by yourself, however, at various points show considerably less lime, and indicate that the average of lime carbonate will be below 70 per cent. If this proves to be the case, from 10 to 20 per cent of a pure limestone, like that at Roseburg, must be added to bring the Marquam rock to the correct composition.

Mr. Eckel assumes the workable thickness of the Marquam stone to be at least 25 feet. From the evident decrease in lime at lower depth, however, I think it safer to assume a depth of 15 feet over an area of 100 acres. This will contain 2,450,000 cubic yards. With the addition of 15 per cent of Roseburg stone, each cubic yard of Marquam stone will make eight barrels of cement, or a total for the whole area of 19,600,000 barrels.

Samples of limestone have been received by the Bureau said to have come from various other points on both sides of the valley northward of the Santiam on the east side and of the Dallas location on the west. Reports of limestone occurrences have also come from particularly the northwest corner counties of the state. Reports of this nature and the receipt of occasional samples both serve to further emphasize the advisability and urgency of conducting careful field work throughout this whole region in order to determine beyond question whether available limestone exists here.

Pacific slope.—With a view to determining the possible occurrence of limestone Mr. A. J. Collier of the Bureau staff examined the rock outcrops along the line of the Pacific Railway and Navigation Company from Hillsboro to Tillamook. Mr. Collier reports as follows:

There are no deposits of limestone large enough for the manufacture of Portland cement. Small seams and concretions of limestone are to be found in the shale near the coast from Mount Hebo on the south to Neahkahnie mountain on the north, and the deposits of tuff frequently carry a small per-

centage of lime carbonate so that they may be used as a fertilizer for acid soils if no other sort of such material is available.

Five miles southeast of Tillamook in Sec. 9, T. 2 S. R. 9 W. is an occurrence of limestone that has been only prospected. The stone outcrops in the east bank of a small stream at this point and 75 feet to the eastward where it has been uncovered in a prospect pit, the drill shows the deposit to have a thickness of at least 10 feet. Northward from the exposure in the creek bed, a series of drill holes has shown the presence of the stone beneath a shallow overburden for over 100 feet. Along the creek both above and below the outcrop shales are found containing occasional concretions of limestone.

To date the prospecting done here indicates the existence of 10,000 tons of the stone and possibly a great deal more. Analyses of several samples from different points show a lime carbonate content ranging from about 73 to upwards of 87 per cent, the remainder being chiefly clayey matter and usually around one per cent of magnesium carbonate. An excellent mortar lime has been made by burning some of the limestone. Experimental applications for soil fertilizer have also proven very satisfactory. A grinding plant is now being installed to furnish ground limestone for the local market.

About one mile up the creek from this locality, and on the opposite side of the stream, A. J. Collier reports the occurrence of another mass of limestone that displays a thickness of approximately 5 feet, and 20 feet higher up on the hillside a large hole that is suggestive of a sink-hole over a limestone cavern.

On Faucet Creek about one and one half miles south of the above occurrence the bed-rock is shale which contains numerous concretions of limestone but none of large size. On the north slopes of Mt. Hebo, Tillamook county, in Sec. 1. T. 4 S. R. 9 W. several seams of limestone, none over a foot in thickness and standing nearly vertical, occur in shales. Similar thin beds and concretions appear along Trask river a short distance below the old toll-gate.

North of Beaver, in T. 3 S. R. 9 W. the rock taken out at the roadside for crushing is a tuff that contains veins and blebs of calcite. This deposit may merit further attention in order to determine its exact nature.

At intervals the question is revived of making use of the beds of oyster shells that occur in many places about Tillamook bay, Coos bay, Netarts bay and other shore points, as a source of

lime. The shells themselves are practically pure lime carbonate in composition as are good grades of limestone. If they can be obtained free from the sand and mud that usually accompany them, and in sufficient and accessible quantities, shell beds may serve as well as any other source to supply lime for fertilizer or cement manufacture. The bulk of such beds is apt to be comparatively small however, and as they are usually found, the shells are largely filled with sand and clayey impurities to get rid of which economically is apt to be difficult.

LIMESTONE IN EASTERN OREGON

Limestones are known to occur at many points in the portion of Oregon that lies east of the Cascade mountains. They have been used in a few readily accessible localities for lime-burning or other purposes. The vast bulk of the known occurrences, however, have not been exploited to any extent and the outcroppings of some of them are so situated within the rugged mountainous areas that present development of them is not economically possible.

In the course of the field work carried on in eastern Oregon by the various Bureau parties, considerable data have been obtained regarding the character and location of limestone beds. Some information has also been hitherto published in reports by members of the U. S. Geological Survey. What follows is a brief summarized statement of existing knowledge relating to the limestone in those sections of eastern Oregon that have been either thoroughly or casually explored and which are at present reached by railroad transportation. The facts are drawn from all available sources.

Columbia river.—Occurring about 1000 feet above the Columbia river at Rufus in Sherman county, is a deposit consisting of interbedded layers of soft lime carbonate and of a pulverulent lava ash. The strata of each are thin, the whole averaging, according to the prospectus of the Portland Cement Company from which these facts are taken, about 47 per cent carbonate of lime. This deposit is believed to be of considerable magnitude.

Somewhat farther up the Columbia, along the sides of the gorge a few miles south of Arlington in Gilliam county, occasional local deposits of marly material occur, some of which appear to contain a high proportion of lime carbonate. The extent of these deposits is not known. Carbonate of lime is a common mineral in this region and is occasionally found filling the seams and cavities in the basalt which is the prevailing country rock.

John Day Basin.—A. J. Collier, in the March, 1914, issue of the Mineral Resources of Oregon, page 39, describes the deposits of limestone in the vicinity of the John Day river as follows.

The limestones have been used as a source of lime for some of the buildings in Fossil. Lime has been burned from time to time in this place. The limestone deposit is situated near the headwaters of a small stream known as Shoo Fly creek in T. 11 S., R. 22 and 23 E. Beginning in S. 24 of T. 10 S., R. 23 E., the rocks strike northwest and southeast and dip at rather high angles to the northeast. There are occasionally small beds of limestone, which crop out on the hills on either side of the creek. In S. 1 of T. 11 S., R. 22 E., at the old quarry there are approximately three beds of limestone, none of which is more than ten feet in thickness, and which strike nearly N. W. and S. E. and stand approximately vertical. Two of these beds are so near together, however, that they could probably be worked as one bed. These beds of limestone can be traced to the north about halfway through section 36 of township 10 south, range 22 east, and to the south they can be traced for an unknown distance. The quantity of the limestone present here is probably not of sufficient extent to warrant any very great developments.

An occurrence of limestone is also found on the south fork of the John Day river a short distance above Dayville in Grant county. The strata here stand nearly vertical and one bed of limestone outcropping at the bank of the river is about 10 feet thick or less. No effort has been made to work this stone.

Baker county.—The limestone resources of the Sumpter quadrangle, chiefly in the vicinity of Sumpter, are referred to by J. T. Pardee and D. F. Hewett in the October number of the Mineral Resources of Oregon, page 70.

Limestone is fairly abundant in the Sumpter quadrangle, its principal exposure being confined to the area of Elkhorn ridge. [Outcrops occur on both the Sumpter valley and the Baker valley sides of this ridge. The former are for the most part high up towards the head of the several branches of Deer creek the most accessible being about 8 miles from the Sumpter valley railroad where Deer creek flows into the Powder river]—Ed. No analyses of these limestones are available, but from superficial examinations it appears that many of them are free from chert or other plainly noticeable impurities and are essentially composed of pure calcium carbonate. Lime has been burned a mile and a half southeast of Sumpter at a small quarry, which has also supplied limestone for flux to the Sumpter smelter. A kiln situated on Marble creek about one mile west of the quadrangle's eastern limit has made a small production of lime for domestic purposes. The more extensive limestone outcrops of Marble Point and vicinity have not been developed, but they can readily be made accessible and may be counted as one of the potential resources of the quadrangle.

Again on page 32 with reference to the distribution and nature of the limestones, Pardee and Hewett say:

The limestone comprises a relatively small proportion of the volume of the series. Its greatest areal exposures are confined to a belt about half a mile in width that extends from Marble Point westward to Deer creek, although a number of very small outcrops are scattered sparingly elsewhere in the argillite area. The limestone outcrops are rather remarkable because they almost invariably occur as small detached areas that have angular boundaries. Most of them range from 50 to 500 feet in width and from 100 to 1,000 feet in length. . . . In color they range from light gray to dark blue and in composition they appear

to be generally almost pure calcium carbonate. Many of the masses have been altered to a white crystalline marble. The detached areas that form the principal belt of limestone for the most part are bounded by straight and parallel lines, one set of which strikes about N. 65° E. and another about N. 50° W. The largest single exposure of limestone, that of Marble Point, occupies an irregular area about three-fourths of a mile in length from east to west, and half a mile in width. Its vertical extent is 1,000 feet or more. In detail, its boundaries are irregular zig-zag lines and the whole appears to be made up of separate angular blocks.

In general the limestones of this belt have been metamorphosed into fine to medium-grained, white to light-blue marbles. Bedding planes are usually indistinguishable, and the rock is traversed by minute fractures healed by thin calcite seams. Weathered surfaces present intricate patterns of etched right lines that separate bluish-gray patches. The small limestone areas scattered elsewhere in the quadrangle are essentially similar to these except that all are not metamorphosed to the same degree. The limestones occur in the upper part of the argillite series, and are interbedded with argillaceous sediments and lie between sheets of eruptive rocks. Owing to the obscurity of bedding planes their thickness is difficult to measure although it has been estimated to range from 50 to 500 feet.

There are several deposits of limestone between Baker and Huntington both in Baker county, in proximity to the O.-W. R. & N. Railroad. Those in the immediate vicinity of Baker that are* of economic importance, are located from one-half to one mile north of Pleasant valley in section 18, T. 10 S. R. 42 E. There are three quarries. One is located in the southeast quarter of the southwest quarter; a second in the northwest quarter of the southwest quarter; and a third in the southwest quarter of the northeast quarter of this section.

The rock is bluish-gray in color and of a dense texture. In places, especially in the first mentioned quarry, it appears to have been brecciated and then recemented. It is here also cut by small veins of a darker colored calcite. A great many samples taken from all of the quarries have been analyzed. The analyses show that the limestone is practically pure calcium carbonate containing only about one-half of one per cent of silica, approximately the same amount of iron oxide and alumina, and a very small percentage of magnesia.

The extent and size of the deposits are as follows:

Quarry in S. E. $\frac{1}{4}$ of S. W. $\frac{1}{4}$ has an opening about 75 feet long, 30 feet wide, and a face 20 feet in height. The limestone outcrops over an area of about one-fourth of an acre.

The quarry in N. W. $\frac{1}{4}$ of S. W. $\frac{1}{4}$ is but a prospect cut, though the limestone is exposed over about 4 or 5 acres. Along the steep hill slope at the south it can be seen to have a thickness of at least 50 feet.

The third quarry referred to has an opening about 100 feet long, 30 feet wide, and a face of 20 feet. The rock is known to cover about 5 acres. In this quarry there is an irregular bed of shaly limestone about 4 feet thick. The dip as measured on this interbedded shaly layer is approximately 40° to the north-westward and the strike N. 25° W. From this it can be seen that the limestone bed is considerably thicker than the 20 feet exposed in the quarry opening.

Formerly the rock from the two quarries that have been worked was hauled to a lime kiln near the old town of Pleasant Valley, which is about one mile northwest of the present railroad station. Some limestone for this kiln was also obtained from a small deposit located in the southeast quarter of the northwest quarter of Section 12, T. 10 S., R. 41 E.

Transporting the limestone from the quarries to a plant at Pleasant Valley can easily be done with an aerial tramway as the difference in elevation between

*Mineral Resources of Oregon, Oct., 1914, p. 158. From the notes of G. E. Goodspeed, Jr.

the two points is about 600 feet. There are volcanic tuff quarries close to the railroad and it has been determined by careful tests that this material can be used with the limestone, replacing shale to a large extent, for the manufacture of Portland cement. The Baker Commercial Club has had such tests made by the Smith Emery Company of San Francisco, also by the Wolverine Portland Cement Company of Coldwater, Michigan, previous to their endorsement of the Intermountain Cement and Lime Works of Baker, which proposes to erect a cement plant in the vicinity of Pleasant Valley.

In a report issued by W. Lindgren* it is stated,

All the sedimentary rocks in the Blue Mountains contain more or less limestone of good quality, interbedded with slates, shales, siliceous argillite, and volcanic tuffs. Very large masses are found in the Eagle creek mountains. Its quality is excellent, but distance from lines of communication has prevented its utilization.

The series of rocks exposed near Huntington also contain many beds of limestone of good quality. One of the largest of these masses, several hundred feet wide, is exposed 4 miles above Huntington on both sides of the railroad. At this point are extensive works which supply the larger part of the lime used in the state of Oregon. Other heavy strata of limestone are exposed at the head of Connor creek and on the hills 4 miles southwest of Durkee.

The argillite series, so greatly developed in the vicinity of Baker City and Sumpter, is less rich in limestone. Smaller lenticular deposits occur about a mile north of the railroad at a point 6 miles southeast of Baker City, and also in the hills 3 miles northeast of Pleasant Valley. At both localities lime has been burned, but only the latter is worked at present. The Elkhorn range contains a few heavy deposits of limestone of thick lenticular form. The most important of these is exposed on Marble creek at an elevation of 5,500 feet. Lime was formerly burned there, but at present the works are idle. At Sumpter and west of that place, limestone is not abundant. A deposit of apparently limited extent is found half a mile north of the city of Sumpter and has locally been used for smelting purposes. At the Winterville placer mines, a short distance below Bonanza mine, another small mass of limestone appears adjacent to serpentine. No work has been done on this.

About 4 miles down the railroad below Durkee the limestone composes a hill several hundred feet in height. The deposit is opened at the railroad and there are kilns at this place for burning lime.

Along the Snake river † in Baker county, from Huntington down to about 20 miles north of Homestead many outcrops of limestones occur on both sides of the river. Near Winslow station on the Huntington-Homestead branch of the O.-W. R. & N. railroad, is a vast ridge of crystalline limestone some four miles long running north and south between Connor and Soda creeks. The rock reaches an elevation of perhaps 2000 feet above the river. The strata stand nearly on edge and an actual thickness of 1500 to 2000 feet of limestone exist in this locality. The railroad runs at the foot of this deposit.

*The Gold Belt of the Blue Mountains of Oregon, U. S. G. S. 22d An. Rp. pt. 2, p. 639.

†The facts relating to these deposits and to the limestones in Wallowa county are in large part from the notes of A. M. Swartley, Bureau mining engineer and G. E. Goodspeed, assistant geologist.

Eight miles north of Homestead, which is the present terminus of the railroad, is a belt of limestone that can be seen paralleling the road for a distance of three miles or more. The available quantity here is inestimable. The stone is conformable with the older greenstones and, being interfolded with them, has suffered alteration and is in many places quite schistose.

Wallowa county.—Outcrops of limestone and marble appear at many points upon the north front of the Wallowa mountain range which overlooks the broad valley of the Wallowa river. Some of the prominent peaks of this range consist in part of conspicuous beds of light-gray crystalline limestone and zones of it may be seen extending for miles at higher altitudes along the range.

The 'Matterhorn' at the east of Hurricane creek is one of these peaks. It is a mountain some 9000 feet in height and of striking appearance because of the enormous volume of white crystalline limestone of which it is largely composed. It is impossible to make even an approximate estimate of the amount of limestone existing in the higher parts of these mountains. In places the beds are hundreds if not thousands of feet in thickness and cover miles in areal extent.

About 5 miles southwest from the town of Enterprise are the quarries of the Oregon Black Marble Company. H. M. Parks in the February, 1914 number of the Mineral Resources of Oregon refers to the black marble of this locality as follows:

The property upon which the marble outcrop was examined belongs to the Oregon Black Marble Company, of which Dr. J. D. Fleenor, of Joseph, Oregon, is secretary and treasurer. It extends in an east-west direction for more than a thousand feet and follows approximately the contours of the hillside. The width of this most easily examined and well-exposed outcrop varies from 50 to 500 feet. The thickness of the bed is known to be more than 500 feet in some of the more favorable exposures. Its strike is approximately east and west with a gentle dip against the slope of the hill of approximately 15 degrees south. Considerable folding is apparent in certain parts of the outcrop, indicating that the entire deposit, so far as has been observed, is the north limb of a synclinal or trough field. Near the most eastern portion a small stream has cut a gorge straight across the beds thus permitting the observation of a good cross-section of a large body of the stone.

The striking feature of the marble is that the color of a large portion of it is almost jet black. It is at least as black as the blackest of slates. The black color is due to the presence of carbonaceous matter in the original limestone which was altered to graphite when the limestone was metamorphosed to marble. The blackest portion seems to be confined to the east 500 feet of the 1000 foot outcrop described above, and from that point west it grades off gradually into the dark grays and mottled marbles so common in many deposits. In the black area there are a few narrow white calcite veins running through the mass with more or less circular spots of white calcite.

Only a small amount of work has been done to make a quarry opening. Something more than 5000 cubic feet of excavation has been made in the hillside close to the gorge of the stream mentioned. The separate beds examined

in the different parts of the exposure vary from 2 to 6 feet in thickness, and usually show the characteristic jointing of limestone. These joints are also from 2 to 6 feet apart. At a depth of 16 feet from the surface, as exposed in the excavation, blocks of 60 to 75 cubic feet can be obtained without difficulty.

The chemical composition shows the rock to be a fairly pure limestone. From the color, one would naturally infer the presence of a considerable amount of impurities, but among a number of samples analyzed there is less than five per cent of insoluble matter present. The products which could be made from this deposit of limestone are lime, marble and building stone. Its chemical composition would indicate that this rock would produce a good grade of lime. This last conclusion is borne out by the fact that a considerable amount of lime has already been manufactured here, and it is said to be of excellent quality. Such a limestone would also, so far as its composition is concerned, furnish the lime for a Portland cement mixture.

Limestone has been quarried and burned for lime on Lostine creek at a point a few miles south of the town of Lostine, which is on the La Grande-Joseph branch of the O.-W. R. & N. railroad. No data are at hand as to the character and accessibility of the limestone at this place.