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Report of Investigations
No. 5

PRELIMINARY REPORT
ON
MAGNESITE DEPOSITS
OF
STEVENS COUNTY, WASHINGTON

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Plate 2. South half of the magnesite belt, Stevens County, Washington	In pocket

INTRODUCTION

The "magnesite belt" lies wholly in Stevens County, extending southwesterly from about 4 miles north of Chewelah to within 2 miles of Spokane River. (Fig. 1.) As outlined, this belt is 31 miles long. On the basis of present information any extension northward is unlikely, while at the southern end there is a problematical extension beneath the Gerome andesite, but this may be cut off by the Loon Lake granite. Transportation facilities are provided at the north end by the Great Northern Railway and U. S. Highway 395, and at the south end by U. S. Highway 10 and State Highway 22 via Davenport.

Although magnesite was recognized by Shedd in Stevens County early in this century in the course of a study of the building stones of Washington,^① it was more than a decade later that the systematic prospecting began.

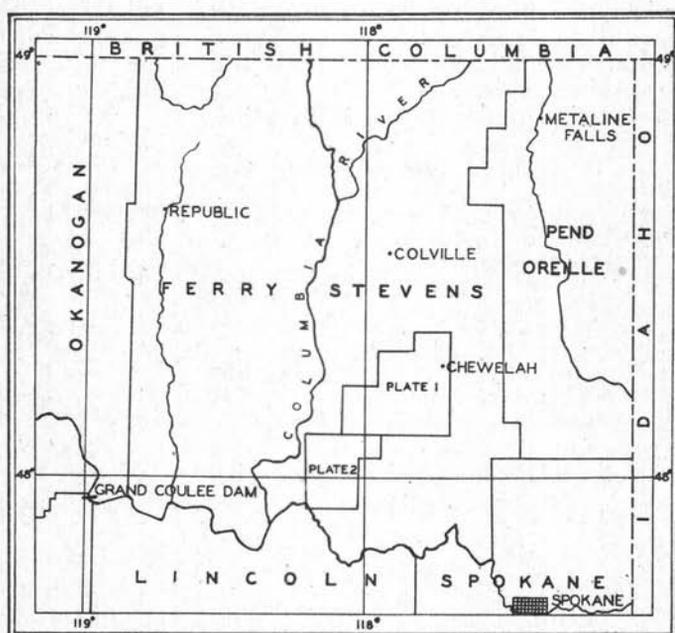


FIG. 1. INDEX MAP

Whitwell and Patty^② have presented a rather detailed account of development during the several years of increased activity. With the cessation of hostilities cheaper foreign ores were again available and development of the Washington deposits was correspondingly slowed down.

Prospecting for magnesite has been continuous since its first commercial utilization here in 1916, and the known occurrences are held by relatively few companies and individuals in fee, or as mineral leases, or as placer claims on United States land. The areas of dolomite containing these magnesite

^① Shedd, Solon, The building and ornamental stones of Washington: Washington Geol. Survey Ann. Rept., vol. 2, pp. 95, 97, 1902.

^② Whitwell, G. E., and Patty, E. N., The magnesite deposits of Washington, their occurrence and technology: Washington Geol. Survey Bull. 25, pp. 16-20, 1921.

bodies, and in which other occurrences not now known may eventually be found, are held in several ways listed in approximately the order of the acreage so held:

1. By individuals and companies in fee as farming, grazing, and timber lands, and as mining claims.
2. By Stevens County,—land open to sale.
3. By the State of Washington,—land open to sale or mineral lease.
4. By the United States,—land in Indian Reservation and land open to preëemption or to the filing of mineral claims.
5. By the Northern Pacific Railway Company,—land open, under certain conditions, for purchase or mineral lease.

In recent years the use of magnesium metal in light structural materials has greatly increased. Beneficiation of magnesite ores by flotation, together with an abundance of cheap power has focused attention on available magnesite resources in the Northwest. Dolomite may come into demand later, although its use is not now contemplated. In the present report, therefore, some attention has been paid to dolomite beds in this area even though they appear to be barren of commercial magnesite.

EARLIER INVESTIGATIONS

The more important results of previous work in the area will be found in the references listed below:

1903. Shedd, Solon, Building and ornamental stones of Washington: Washington Geol. Survey Ann. Rept., vol. 2, pp. 87-103.
The occurrence of magnesite is mentioned for the first time, but its use for a building stone only was considered.
1913. Shedd, Solon, Cement materials and industry in the State of Washington: Washington Geol. Survey Bull. 4, pp. 124-126, 246.
Some new analyses of magnesite are included, most significant of which is a location southeast of the Red Marble quarry.
1918. Yale, C. G., and Stone, R. W., Magnesite: U. S. Geol. Survey Mineral Resources 1917, pt. 2, pp. 71-75.
A brief account of the geology is given; a significant statement is the probable Pre-Cambrian age of the rocks, and the possible influence of greenstone masses on genesis of the deposits is first mentioned. See other papers by Stone.
1919. Jenkins, O. P., Notes on the possible origin of magnesite near Valley, Washington: Econ. Geology, vol. 13, pp. 381-384.
The idea of ground water is first mentioned in association with basic masses and possible origin of the deposits. Included also is a sketch showing an interpretation of the structure at the Red Marble-Double Eagle-Keystone deposits.
1920. Weaver, C. E., The mineral resources of Stevens County: Washington Geol. Survey Bull. 20, 350 pp.
Rocks in the magnesite area are mapped and given stratigraphic names, and a regional structural interpretation is presented. The magnesite is referred to the Stensgar dolomite and its secondary character is recognized, and its age is regarded as post-deformation.

1921. Whitwell, G. E., and Patty, E. N., The magnesite deposits of Washington, their occurrence and technology: Washington Geol. Survey Bull. 25, 194 pp.
The emphasis of this report is on the technology of magnesite. Weaver's work is followed with data added on several deposits, but considerable attention is paid to origin, and the conclusion is reached that the magnesite was formed by local leaching on the ocean bottom then recrystallization by metamorphism later.
1922. Petrascheck, W., Kristilliner magnesit in Amerika: Montanistische Rundschau Jg 14, no. 12, 262-263 (not seen).
1924. Bain, G. W., Types of magnesite deposits and their origin: Econ. Geology, vol. 19, pp. 422-423. Also Master's thesis presented at McGill University (not seen).
Brief mention is made of the Stevens County deposits and the concept of solutions rising from depth along the axes of pitching folds is presented.
1927. Siegfus, S. S., Some geological features of the Washington magnesite deposits: Eng. Min. Jour., vol. 124, pp. 853-857.
The magnesite is considered as a sedimentary deposit.
1927. Willis, Bailey, Some geological features of the Washington magnesite deposits: Eng. Min. Jour., vol. 124, pp. 853-857.
The magnesite is recognized as a secondary mineral in dolomite, restricted to a position beneath or near overthrust faults, and is usually protected from erosion by overthrust masses of quartzite. A private report by Willis was made for the Northwest Magnesite Company following a 10 or 11 week survey in 1920.
1928. Jones, R. H. B., Notes on the geology of the Chewelah quadrangle: Northwest Sci., vol. 2, pp. 111-116. Also unpublished manuscript, "Geology and mineral resources of the Chewelah quadrangle," with geologic map, is on file in the Division of Geology.
Great overthrust faults are thought to have displaced the rocks throughout the quadrangle. The Addy quartzite is pictured as having been thrust above, and in places as thrust outliers on, the rocks of the magnesite belt.
1934. Landes, H., The mineral resources of the Columbia River basin in eastern Washington and parts of northern Idaho: Rept. Dist. Eng., 73d Cong., H. D. 103, no. 2, pp. 1083-1086.
New estimates of tonnage are given for the larger deposits, particularly the Red Marble, which is stated to contain some 17,000,000 tons of magnesite.
1936. Glover, Sheldon L., Nonmetallic mineral resources of Washington: Washington Div. Geology Bull. 33, pp. 61-64.
Some features of the relation of magnesite to dolomite, the problem of estimating tonnage, uses, occurrence, and production figures are mentioned.
1938. Hodge, E. T., Market for Columbia River hydro-electric power using Northwest minerals, Section I, Northwest Magnesia Ores, vol. 1, pp. 34-72, War Dept., North Pacific Div., Corps of Engineers.

A description is given of the Finch and Allen-Moss deposits, including cross sections and probable limits of the ore bodies. A geologic map of the area is included which appears to be a reproduction of most of that made by Willis. Conservative statements on reserves are made for a few of the deposits. Much of this work is a description of mining and milling practice.

1939. Culver, Harold E., Some geologic aspects of the magnesite deposits of Washington: State College of Washington Eng. Exp. Sta., Eng. Bull. 61, pp. 19-23.

This paper gives an outline of the stratigraphy of the magnesite belt, states the difficulties of making estimates of reserves, and emphasizes the dependence of these estimates on an adequate hypothesis of origin of the deposits.

FIELD WORK

The present investigation was started in 1934, when a preliminary examination was made of the principal deposits in the northern half of the developed belt. Large-scale maps were made of most of the workings showing the position of the main magnesite bodies. Lump samples were taken for analysis as a basis for determining not only the grade of the magnesite sampled but what areas should be given particular attention. In succeeding years further study was undertaken of other portions of the belt, the final work being completed in April 1941.

ACKNOWLEDGMENTS

The writer is indebted to Mr. E. A. Garber, General Superintendent of the Northwest Magnesite Company of Chewelah; and to Messrs. Sargent and Greenway, who have generously contributed information, particularly on the Finch and Allen-Moss deposits. Important contributions have also been made by residents throughout the area, among whom should be mentioned particularly Messrs. C. F. Allen, Fred Kirkwood, W. L. Nilsson, Ira Jeffries, and D. J. Quast.

Special thanks are due Mr. Henry A. Doerner, in charge of the Pullman Station of the U. S. Bureau of Mines, for making possible the chemical examination of specimens collected in the field.

ROCKS OF THE MAGNESITE BELT

The group of strata which encloses and for the most part underlies the magnesite deposits is predominantly argillites, slates, and phyllites, with subordinate interbedded quartzite and dolomite. These rocks, designated the Deer Trail group, are overlain apparently unconformably by schistose conglomerate and old lavas now altered to greenstone. Above the greenstone, but not demonstrably unconformable, lies a thick mass of quartzite, which in turn is overlain by fossiliferous Lower Cambrian limestone. The rocks of the Deer Trail group have been intruded in places by small-scale basic sills, dikes, and plug-like masses which are now in places schistose greenstone; and both the Deer Trail group and the overlying beds of altered sedimentary and extrusive rocks have been intruded by a granitic batholith with the usual stocks, bosses, and plugs as well as dikes or sills of fine-grained granite or aplite. Certain undeformed dike-like masses of diorite are referred tentatively to this batholith.

DEER TRAIL GROUP

This great group, which was designated by Weaver to include the Stensgar dolomite, extends from northwest of Chewelah southwesterly almost to Spokane River. Both on the east and west lie younger rocks. The total length of outcrop is more than 30 miles, while the belt ranges from less than 2 miles on the northeast to 6 miles on the southwest.

Although the Deer Trail group consists predominantly of slates that are banded throughout and show varying degrees of metamorphism, there are included two main beds of quartzite and two of dolomite. The upper quartzite member crops out 3 miles north of Finch quarry. It extends discontinuously to within 3 miles of the Spokane. At one place a thin slate member lies within the quartzite, at another there is a basal conglomerate, and at another a basal ferruginous zone. The upper quartzite in most places is overlain by the topmost slate of the Deer Trail, but west and north of the Finch quarry there is an overlap of greenstone, and at the south an overlap by the schistose conglomerate. Gray slate three or four hundred feet thick normally separates this upper quartzite from the Stensgar dolomite below. For the purposes of this study the important member of the Deer Trail assemblage is this magnesite-bearing Stensgar dolomite named by Weaver. It crops out at numerous points throughout the 30-mile extent of the Deer Trail group. The limits of the Stensgar dolomite shown on Weaver's map have been extended at both ends, but a more important modification of the earlier map is in the number of discontinuities in the central part of the belt. Present data hardly permit the assumption of continuity beneath the surficial cover of soil or glacial drift.

Lithologically the Stensgar is a thin-bedded, predominantly bluish-gray dolomite. It is fine grained to dense generally, but in places is a medium- to coarse-grained marble. Chert lenses and nodules are not uncommon. Where more completely exposed, as at the north end of the belt, the Stensgar shows a reddish to pinkish basal zone about 100 feet thick, but above and elsewhere it is in general buff. In most places the thickness appears to be within 300 and 350 feet, but at the north it is not less than 700 feet. Where it appears to have still greater thickness, as at the Keystone quarry, it seems probable there is partial duplication by folding or by faulting. North of Colville Valley the Stensgar is in contact with the greenstone which overlies

the Deer Trail rocks. This is believed to be an overlap relation rather than one of faulting. Below the dolomite is a considerable thickness of Deer Trail slate, for which details have not been worked out. Distinctive zones have been recognized, as in the vicinity of the Red Marble quarry, where the slate is purplish gray with pistachio green bands.

The lower prominent quartzite member of the Deer Trail group appears east of the Red Marble quarry, extending from there southward to the Springdale-Hunters road. It is overlain by a gray dolomite bed about 100 feet thick and underlain by a distinctive slate zone that is dark gray to black with white bands. Both the quartzite and dolomite are repeated in outcrops by folding and faulting. Other minor lenses of either quartzite or dolomite have not been mapped for this report.

The thickness of the Deer Trail group is problematical, but it appears to be more than 30,000 feet at the southwest end of the belt. No part of this appears to have been duplicated by strike faulting. On the basis of the Lower Cambrian fossils found in the limestone of the upper group it seems very probable that the Deer Trail group unconformably below is of Pre-Cambrian age.

HUCKLEBERRY CONGLOMERATE

This formation crops out in places north and west of the Finch quarry, then follows along the east side of Huckleberry Mountain and continues to a point 2 miles southwest of the Springdale-Hunters road, where it is cut out by the granite. It reappears a mile north of the Spokane Indian Reservation boundary. Much of this formation is a pebble conglomerate of quartzite, argillite, and carbonate rocks. Generally schistose, this secondary structure is not apparent at the southwest, where the formation becomes a hard flinty hornfels with the carbonate fragments apparently converted to hornblende. The coarseness of fragments increases northeastward concurrently with a diminution in thickness. The conglomerate seems to have been deposited on the eroded surface of the Deer Trail rocks and ranges in thickness from a few hundred feet at the north to approximately 3,000 feet at the south. It is tentatively considered as Lower Cambrian and is overlain by what appears to be Lower Cambrian greenstone in overlapping relations.

HUCKLEBERRY GREENSTONE

This formation crops out north of Colville Valley, then appears to the south in two belts, one of which extends some 9 miles to the south just west of the Finch quarry, while the main mass follows the east slope of Huckleberry Mountain, crosses the divide west of Red Marble quarry, and finally wedges out about 10 miles farther south.

The rock is predominantly composed of metamorphosed basaltic flows in which the ferro-magnesian minerals have been chloritized. In places ovoid dark-green spots suggest distorted vesicles, and in places on the margin of the mass the greenstone is thoroughly schistose. No pillow structures have been noted. The thickness ranges from a maximum of about 3,000 feet on Stensgar Mountain to a few hundred feet at the north and south ends. It overlaps not only the underlying conglomerate but also the upper portion of the Deer Trail group, including the Stensgar dolomite. It appears to wedge out laterally beneath the Addy quartzite. On the basis of Lower

Cambrian fossils in the overlying limestone it is tentatively considered to be Lower Cambrian in age.

ADDY QUARTZITE

As originally described by Weaver the Addy quartzite included both the underlying greenstone and the conglomerate which have just been described. It has a wide areal extent in Stevens County, only a part of which is considered in this report. Within the area mapped it forms the hills north of Colville Valley (33-40), most of Huckleberry Mountain, and has been replaced by intrusive granite in sec. 25, (30-37). Much of the mass is a bluish-gray, fine-grained, firmly cemented quartzite. It is alternately thick and thin bedded, and where observed in the course of the magnesite investigation does not show significant argillaceous or conglomeratic interbeds. Where clearly exposed in sec. 7, (30-38) there is a gritty, slightly conglomeratic basal zone which does not show fragments of the underlying greenstone. Jones^① has observed these same features at the base of the Addy northeast of Colville Valley. The thickness of the formation in sec. 7, (30-38) is at least 3,000 feet and may be as much as 5,000 feet. Throughout most of the magnesite belt the Addy quartzite lies on greenstone, but at the south it locally overlaps that formation to lie upon the schistose conglomerate. It in turn is overlain by what are presumably extensions of the Old Dominion limestone of Weaver which contain fossils that have been identified as the brachiopod, *Kutorgina cingulata* (Billings) of Lower Cambrian age. This limestone lies with apparent conformity upon the Addy so that its upper portion is with little doubt of Lower Cambrian age, and the whole is tentatively so designated.

UNDIFFERENTIATED LIMESTONE

On the map accompanying this report a number of masses of limestone are shown which can not be placed accurately in the stratigraphic column. For the purposes of the magnesite investigation they are unimportant, but some notice is desirable since they might otherwise be confused with other carbonate rocks. The Old Dominion limestone of Weaver does not appear on the area here mapped, but there is a small southeastward continuation of Weaver's area at the north edge of the map as determined by Jones.^② This lies in sec. 22, (33-40) and contains the Lower Cambrian fossils previously mentioned. This mass is not in direct contact with the Addy quartzite on the west and hence this introduces a slight uncertainty regarding the relationship, but at other points in this region a limestone bearing Lower Cambrian fossils overlies quartzite referable to the Addy in the type area. On plate 1 there are shown several masses of undifferentiated limestone near the west margin. It has been suggested that these may be the Old Dominion limestone, but the structural and stratigraphic evidence is too insecure to warrant that designation now. In secs. 10, 11, and 12, (31-39) are three masses which are included in this category of undifferentiated limestones. On plate 2 extending both north and south beyond the limits of sec. 1, (29-37) a belt of limestone appears which for the present is left in this class.

^① Jones, R. H. B., Geology and mineral resources of the Chewelah quadrangle: Washington Div. of Geology. Unpublished report. 1929.

IGNEOUS ROCKS

Two sets of igneous rocks are recognized in the area under consideration. These are a series of basic hypabyssals and some later plutonics. The rocks of the first series, including dikes, sills, and plug-like masses, are found to have intruded the Stensgar dolomite and other dolomite members of the Deer Trail group, but are not known to have penetrated the post-Deer Trail sedimentary rocks. Schistose in many places, they appear to have been injected prior to the main period of regional deformation. Some writers have considered them genetically connected with the deposits of magnesite. The plutonic masses are granitic in character and lie mainly at the southwest end of the magnesite belt where mapped by Weaver as the Loon Lake granite. Small stocks, in part porphyritic, appear on either side of the belt at the north and near the boundary of the Spokane Indian Reservation at the south. Small bosses a few hundreds of feet across occur near the Allen quarry and also in secs. 19 and 30, (30-38). Two of these have intruded the Stensgar dolomite and show contact metamorphic zones about them. Certain dike-like masses of dioritic composition are shown on plate 1 in sec. 26, (31-38) and secs. 3 and 9, (30-38). These lie essentially parallel to the strike of the enclosing metamorphic rocks but are free from evidence of deformation. They are tentatively considered as differentiates of the Loon Lake batholith.

STRUCTURE

Determination of the structure of the rocks in the magnesite belt presents many difficulties, chief of which is the lack of a completed stratigraphic column. For the purposes of this report it is unnecessary to go into the structural problems, and so no attempt is made to go beyond a description of the major structural features.

The rocks of the magnesite belt have been greatly folded and faulted. The maps show a general northeasterly trend of stratigraphic units. Dips range from essentially vertical at the southwest end of the belt to lower westerly dips at the northeast end. The Deer Trail rocks show increasing structural complexity from southwest to northeast.

Folds

The rocks at the southwest end of the magnesite belt show both vertical dips and slight overturning to the northwest. The tops of all beds are to the northwest, and no part seems to be duplicated by strike faulting. It is concluded that the Deer Trail and overlying rocks here form the west limb of an overturned anticline. Traced northward, this west limb of the fold exhibits numerous large-scale drag folds. These folds pitch northward and are overturned to the southeast. Many of them are thrust faulted along or close to their axial planes.

One such fold causes the Stensgar dolomite and upper quartzite member to swing northeastward from the Red Marble-Midnight deposits to the Finch-Allen-Moss quarries. The anticlinal axis trends northward from the Keystone-Double Eagle area. The swing of the Stensgar and upper quartzite member to the north or northwest at the Finch is apparently due to a northward-trending syncline just west of the Finch quarry. Two miles north of the Finch quarry the Stensgar swings sharply to the northeast on a northwestward-pitching drag fold.

In sec. 21, (33-40) the Addy quartzite, Huckleberry greenstone, and Deer Trail slate are involved in a drag fold pitching northeastward.

The greenstone immediately west of the Finch quarry presumably has been separated from the mass on the east slope of Huckleberry Mountain by thrust faults along the axis of a pitching anticline.

Faults

Both thrust and normal faults occur in the magnesite belt but the former appear to be the more important. The most probable positions of some of the thrust faults have been indicated on the maps accompanying this report. The most westerly fault is first recognized in the region of the U. S. Magnesite quarry and can be traced northeastward past the Red Marble and Midnight deposits. It probably extends into the area west of the Finch quarry. South of the Red Marble, dikes of aplite appear to have risen along this fracture. A second fault, half a mile east of the Red Marble, is postulated on the repetition of a marker horizon in the slates below the Red Marble dolomite. On this basis all three parallel bands of dolomite here are referable to the Stensgar. This second thrust very probably cuts out the Stensgar east of the Double Eagle quarry and may pass on northeastward to bring about the duplication of the Stensgar and upper quartzite member of the Deer Trail rocks at the Nogue deposit, (sec. 4, 31-39). The trace of a third principal thrust fault is believed to pass somewhere east of the Keystone, perhaps through the southeast corner of sec. 4. This and the second fault mentioned are in direct line with a postulated fault in 33-40 where the Addy quartzite and underlying Huckleberry greenstone are duplicated.

Normal faults are most conspicuous in the Finch and Allen-Moss quarries. These are possibly related to the small intrusive at the north end of the Allen-Moss deposit. Another normal fault occurs in the Keystone quarry and has been shown in diagram by Willis.^① These faults are inconspicuous in the natural outcrops, but many probably will be revealed in quarrying operations. One other fault deserves to be mentioned. This appears to cause duplication of the Stensgar at the Turk magnesite deposit and to offset the overlying upper quartzite member of the Deer Trail group in sec. 25, (30-38).

The argillaceous rocks are mostly slaty, although some show so little cleavage that they are more properly classed as argillites, and others have been carried to the extreme stage of phyllites and schists. Flow cleavage strikes generally N. 20° E., and this is also the trend of most of the thrust faults.

^① Willis, Bailey, *Geologic structures*: McGraw-Hill Book Co., New York, 3d edition, p. 269, 1934.

MAGNESITE DEPOSITS

MINERALOGY

In general throughout the Stevens County belt the magnesite is of the common straight magnesian carbonate type. Little or none of it appears to contain enough iron carbonate to be classed as breunnerite. Some white vein material in the magnesite of the Crosby deposit resembles ankerite, but the test for calcium was negative, and on the basis of higher specific gravity this material may be breunnerite. Calculation of some of the analyses of reddish magnesite from the Red Marble deposit, even on the assumption that the iron present is in the form of siderite, reveals less than 5 percent iron carbonate.

Brucite occurs in some of the deposits in minor amounts. It occurs at the Keystone quarry as a lens 20 feet wide and 50 or more feet long which lies transverse to the general trend of the magnesite and dolomite mass.

Other minerals widely distributed but nowhere abundant include talc, sericite, quartz, tremolite, and some undetermined asbestiform minerals. Locally present are pyrite, galena, and sphalerite. This mineralization is later than the magnesite and is probably genetically related to the small granitic intrusive exposed several hundred feet north of the Allen-Moss quarry.

TEXTURE OF THE MAGNESITE AND DOLOMITE

The texture of the magnesite ranges from coarsely crystalline, with crystal faces nearly half an inch long, to as fine as brown sugar. There is often an intermixture of textures, the coarser phases apparently following along original bedding planes in the dolomite with finer textures between. At the Red Marble coarse, dark bands have apparently formed along bedding planes, commonly no more than half an inch wide. These are separated by finer, lighter colored layers which seem to be slightly higher in calcium than the narrower and coarser bands.

In places no textural variations in the magnesite follow the original bedding. Elsewhere the absence of bedding may result from original massiveness of the dolomite.

The most uniform of the deposits is that east of Turk, where the coarse-grained magnesite shows little difference from the adjacent dolomitic marble.

The enclosing Stensgar dolomite is mostly fine grained, and is locally coarse to medium marble in the vicinity of the Turk magnesite body just mentioned, and in the vicinity of the Queen and Seal mine. Fine grained to dense textures prevail in those few outcrops found on the Spokane Indian Reservation, including the Orazada mine. The coarser textures are always around intrusive masses of granitic rock.

STRATIGRAPHIC POSITION

Present data on both the structure and the stratigraphy of the rocks of the magnesite belt are quite insufficient to permit positive statements regarding the stratigraphic position of bodies of magnesite within the Stensgar dolomite. The following statements must therefore be considered suggestive rather than final.

The magnesite appears to occupy the upper part of the Stensgar dolomite at the Finch and Allen-Moss deposits, the Keystone, the Red Marble, and perhaps the Double Eagle. The small magnesite mass in the Phoenix

deposit is considerably below the top of the enclosing dolomite. The magnesite zone at the U. S. Magnesite quarry is apparently along the base of the enclosing dolomite. In the Turk body magnesite apparently makes up the entire width of the Stensgar, and apparently the highest grade of ore is on the bottom side and next to a postulated fault.

Within many masses of dolomite the distribution of magnesite is extremely irregular. It is largely present in ill-defined masses and at most points appears to make up only a small part of the Stensgar formation.

ORIGIN

The origin of the magnesite has been considered by almost all writers who have examined the deposits. Opinions on the genesis of the magnesite have been summarized by Culver^① as follows:

"The more important, measured by probability, of the origins so far advanced fall into two main groups. First there are those which regard the magnesite as an original deposit, and second, those which regard it as a secondary deposit formed from the dolomite by some process of solution and redeposition. In the first group are two distinct ideas, one suggesting the magnesite was formed as an original marine deposit at the time of the dolomite sedimentation, while the other provides for the later addition of magnesium carbonate through the medium of thermal magnesium-bearing waters of magmatic origin. Without going into the matter in any detail it may suffice here to state that the field evidence includes no facts which suggest that either of these hypotheses is correct. The extremely irregular occurrence of the magnesite in the dolomite belt serves, rather, to emphasize the improbability that the present deposits of magnesite are original. Nor is there evidence of the introduction of thermal waters in the presence of minerals other than magnesite within the supposed impregnated zones of the rocks.

A variant of these "original deposit" theories supposes a sediment of mixed salts of magnesium and calcium to have been laid down in the first place. Then, by some unspecified, but not improbable, process the lime carbonate was removed before there was opportunity for dolomite, the double carbonate, to be formed, thus leaving the magnesium carbonate as found today. This last hypothesis may really be considered a member of both groups since it involves both an original magnesium sedimentation and a subsequent modification, or metamorphic phase, by percolating solutions.

In the second group of hypotheses may be included those involving primarily a change in the composition of the original carbonate rock through the agency of percolating solutions resulting in the deposition of magnesite within the mass of the dolomite. No reference is made to thermal conditions and hence cold, probably meteoric, waters may be assumed to have been the active medium of alteration.

Without relating detailed points of evidence, it is perhaps enough to point out that many, if not most, of the physical and chemical features of the magnesite deposits appear to fit in very well with the idea of alteration of an original dolomitic mass. The distribution of the magnesite, its variability in content of quartz and calcite, the minute interfingering of magnesite and dolomite, and in some instances a gradation, are all features which favor a secondary, or alteration, hypothesis."

The reader is referred to the list of references accompanying this report for more detailed discussion of hypotheses of origin.

Few will doubt the secondary nature of the mineral in the dolomite, but it is by no means clear whether magnesite was deposited before the major deformation of the area or later. This point is important in as much as it will have a bearing on future prospecting. If the mineral is post-deformation, and is localized along major fractures, these must be considered as the

^① Culver, Harold E., Some geologic aspects of the magnesite deposits of Washington: State College of Washington Eng. Exp. Sta., Eng. Bull. 61, pp. 21-22, 1939.

most probable places where additional deposits of the mineral are to be found. If the mineral is pre-deformation, its occurrence will show no relation to structures.

On present data it is believed that the magnesite is almost entirely restricted to the Stensgar dolomite. It is difficult to understand why magnesite is not extensively deposited in lower dolomite members of the Deer Trail rocks. Some have called attention to basic dikes and plugs as agents instrumental in the formation of the magnesite. In some places there appears to be a relationship to these intrusives, but not in others.

Although certain points are not clear, it seems probable that the magnesite is post-folding, and that solutions from batholithic masses have risen along lines of major shearing and faulting to replace parts of the dolomite.

EXTENSIONS OF THE STENSGAR DOLOMITE

On the basis of structural and stratigraphic relations that seem to prevail in the belt, certain areas may be designated as favorable for extensions of the Stensgar dolomite. One of these is the east slope of Stensgar Mountain west of the Red Marble and Crosby deposits. The Stensgar at the Midnight deposit is probably continuous south to the Davis deposit, and from there southwest to where it joins the segment exposed along the road to Stensgar Lookout half a mile west of the Red Marble.

The Stensgar at the Nogue deposit in the center of sec. 4, (31-39) probably continues southwestward at least into the north half of sec. 8.

There appears to be a gap in the continuity of the Stensgar in the area south of the Cleveland mine in secs. 9 and 16, (30-38). Evidence is not conclusive as to whether the Stensgar is faulted out or covered by surficial deposits.

DESCRIPTION

Area north of the Finch quarry

Dolomite is exposed along U. S. Highway 395 on the north side of Colville Valley, and lies in secs. 29 and 32, (33-40). It crops out also on the south side of the valley in secs. 8, 17, 18, and 19, (32-40), and sec. 13, (32-39).

The mass north of the valley has a length of a mile, a width of 500 to 1,200 feet, and is 1,700 to 2,300 feet above sea level; that south of the valley is at least 4 miles long, mainly 1,200 feet wide, and 2,200 to 3,100 feet above sea level.

The rock beside the highway is all dolomite. Its upper and much the greater part weathers buff, but the beds that form a basal zone are red, pink, purple, and lavender on weathered surfaces. Much of the dolomite is thin bedded and fine grained. The dolomite south of the valley is more grayish white than buff, although the reddish basal zone appears again in sec. 19.

Very little prospecting has been done in the dolomitic rocks north of the Finch quarry. The dolomite is being quarried in sec. 32, (33-40) by the Manufacturers Mineral Company of Seattle. An old shaft and other workings are located near a greenstone dike a quarter of a mile north of the highway.

The dolomite north of the valley strikes N. 10°-20° E. and dips 40° NW. Along the highway the formation is at least 700 feet thick, including the 100 feet of varicolored basal beds. South of Colville Valley the dolo-

mite has a considerable range in strike and dip, especially in the S $\frac{1}{2}$ sec. 18 where the dolomite and perhaps the quartzite have been compressed into a small pitching anticline and syncline.

Finch area

The dolomite which encloses magnesite at the Finch quarry crops out in the center SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 30, (32-40) at 2,100 feet above sea level. It trends east of north for half a mile until an elevation of 2,700 feet is reached in the SW $\frac{1}{4}$ sec. 19. Here the dolomite swings to west of north and maintains the same elevation as far as the center E $\frac{1}{2}$ sec. 13, (32-39).

The quarry extended nearly across the whole width of outcrop in 1934, its west and east limits being respectively 300 feet and 900 feet east of the township line. The north and south limits, including old workings, were respectively 550 feet and 150 feet from the east center line N $\frac{1}{2}$ sec. 30. The main working level was near 2,200 feet above sea level, or about 100 feet below the east rim and highest part of the quarry. The ore body, including some low-grade magnesite, dolomite, chert, altered dikes, and other components, had been quarried to the slate on the west and the dolomite on the east. On the south the best grade of magnesite lay north of a fault that extended across the quarry limits. Magnesite south of the fault seemed to occur intermixed with dolomite, and was being prospected by short adits.

The dolomitic host rock is fine grained to dense, and bluish gray. Much of it is thin bedded. The beds strike N. 5°-10° E. and dip 70° NW. in the southwest part of the quarry, but on the east and north sides the strike is N. 5°-10° W., and the dip, 45°-65° SW. Numerous faults were seen, most of which strike nearly east and dip mainly north. The pitch of striae on these faults was both east and west at low angles.

Outcrops north of the Finch quarry are small and not abundant. One at about the place where the trend swings northwestward is a buff-weathering fine-grained dolomite containing many lenses and nodules of chert. During the earlier exploration for magnesite a claim called the Indian was located a little over half a mile north of the Finch quarry or in the SW $\frac{1}{4}$ sec. 19. An outcrop in the NW $\frac{1}{4}$ NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 19, however, appears to be dolomite. Hydrothermally altered carbonate rock and clay-like material can be seen in some old pits and trenches in the SE $\frac{1}{4}$ sec. 13.

Allen-Moss area

The approximate center of the Allen quarry is the common corner of secs. 25, 36, 30 and 31, (32-39) and (32-40) respectively. The Moss workings lie 500 to 800 feet southwest of the Allen at the opposite end of the same mass.

The dolomite crops out 1,500 feet north of the Allen quarry at 2,100 feet above sea level, then rises in 3,000 feet to 2,300 feet at the south end of the outcrop. Its maximum width is 400 feet.

The factors that affect the grade of ore at the Finch are much the same in the Allen-Moss. Unreplaced masses of dolomite within the magnesite mass, or wedge-like masses of it that seem to be faulted into juxtaposition with magnesite, appear to be more abundant than at the Finch. The continuity of the ore body both north and south is uncertain. Extension of

the Allen workings to the north must ultimately encounter a biotite granitic plug with its accompanying zone of metamorphic alteration products. Much of the faulting, hydrothermal effects, metallic mineralization, and even the magnesite, in both the Allen-Moss and Finch quarries, may be related to this granitic intrusive.

Woodbury area

The Woodbury is located in the NW $\frac{1}{4}$, sec. 1, (31-39) between 2,200 and 2,300 feet above sea level. There are five outcrops here. The largest and centrally located outcrop has been prospected by a tunnel that has caved. Quarrying was done along the face north from the east portal of the tunnel. Analyses of samples taken from the 30-foot face are given as Nos. 20, 22, 60, 62, and 65 in the table.

The mineralization is mainly a development of magnesite as small irregular replacements along bedding planes in the dolomitic host. Analysis 20 represents the best-appearing material in the quarry face, and 22 is a narrow veinlet along bedding in the dolomite.

Mountain View area

This name is here applied to a deposit located about half a mile southeast of the Mountain View school near the center E $\frac{1}{2}$ sec. 3, (31-39) at 2,500 to 2,600 feet above sea level. Coarsely crystalline magnesite occurs at the southwest end of the largest outcrop of dense to fine-grained bluish-gray dolomite. A few quartz veins cross the magnesitized zone at its south end.

Phoenix area

The Phoenix lies close to the SW corner sec. 3, (31-39), at 2,800 to 2,900 feet above sea level, and on the north side of a gully that follows close to the base of the outcrop of dolomite. Roads to the northeast and southwest are respectively half a mile and a mile from the deposit.

The dolomite may be followed for some 800 to 1,000 feet in a northeasterly direction and is 300 feet wide.

Coarsely crystalline magnesite forms small irregular patches near the southwest end. Some of these patches have been prospected by drilling. Analyses of the magnesite and of the dolomite are listed as Nos. 29 and 20-A respectively.

The dolomite strikes N. 40°-45° E. and dips 50° NW. on the upper side close to its contact with gray slate. Quartzite above the slate bed strikes N. 70° E. and dips 40° NW.

Nogue area

The Nogue deposit lies in the SE $\frac{1}{4}$ sec. 4, (31-39), half a mile west of the Phoenix, and at 3,300 feet above sea level. This deposit is much like that of the Phoenix and Mountain View. The dolomite is fine grained and contains patches of magnesite that are more coarsely crystalline. The dolomite strikes N. 30° E. and dips 60° NW. It is overlain by a gray slate which in turn is overlain by massive quartzite. The sequence of dolomite, slate, and quartzite suggests a normal depositional order that has been repeated by faulting, not only once, but a second time, as would appear from dolomite that underlies quartzite near the center of sec. 4.

Keystone area

Dolomite in the vicinity of the Keystone quarry crops out in the SW $\frac{1}{4}$ and center of sec. 9, (31-39) from which it may be traced northward into sec. 4 and southwestward to a point 1,000 feet east of the S $\frac{1}{4}$ cor. sec. 8. The main Keystone quarry is located 400 feet east of the W $\frac{1}{4}$ cor. sec. 9, and is reached by roads leading southwestward from U. S. Highway 395 near Chewelah, or westward from Valley via Waits Lake.

The width of outcrop at the quarry is 1,100 feet, measured from the slate contact at the northwest to the old workings in the altered area surrounding basic injections. Other small outcrops east-southeast of the main quarry, and northeast of it near the center of sec. 9 suggest that an area half a mile wide is mainly underlain by dolomite. The quarry is 3,700 feet above sea level, but the dolomite mass as a whole lies between 3,000 and 4,000 feet.

The dolomite mass has been most abundantly replaced by magnesite in its upper or northwest side adjacent to slate, at the site of the main quarry. Along the quarry face the magnesitized zone is 250 to 300 feet wide. It extends southwest at least 200 feet and probably considerably farther. Knob-like outcrops 300 to 400 feet northeast seem to be principally magnesite, but the intervening area must be trenched or drilled to show continuity with the mass at the main quarry.

The southeast side of the dolomite mass at the Keystone has been intruded by basaltic sills, dikes, and plugs. The intruded rock is minutely fractured and altered to a brucite-like material. Much of it is soft and may have been the source of the rock that was studied by F. W. Clarke and named pseudo serpentine. Although Clarke found considerable brucite in the rock he described, the principal deposit of that mineral occurs in the main Keystone quarry along a fault zone. The brucite lens was 20 feet wide on the northwest and pinched out in 150 feet southeastward. Most of it was on the foot wall (northeast) side of the fault.

Midnight area

Dolomite at the Midnight magnesite deposit lies in the SE $\frac{1}{4}$ sec. 7, (31-39). The deposit may be reached by two roads, one along Huckleberry Creek and the other via the Keystone quarry, both of which join an old road to the Midnight at the Kline farm. The outcrops lie near the head of a tributary of Huckleberry Creek at about 4,000 feet above sea level and at the foot of Huckleberry Mountain. There are four small outcrops, one about 1,200 feet north, and the others some 600 feet south of the end of the road. Development has been done at one deposit which is 350 feet by 150 feet, and a quarry 40 by 14 by 5 feet has been opened. About 500 feet southwest of the quarry is a 50-foot shaft.

Double Eagle area

The Double Eagle deposit comprises two outcrops, both of which have been opened by quarrying. The larger of the two lies in the NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 18, (31-39); the other lies 1,500 feet west. Dolomite about both quarries is poorly exposed, but its width is judged to be 300 feet, and it seems probable that the two quarries are connected by dolomite beneath a thin covering of rubble. Dolomite is difficultly traceable down hill along the east line of sec. 18 to its southeast corner.

The east quarry is 4,100 feet, and the west, 4,000 feet above sea level; both are some 800 feet above old kilns in a ravine on the south.

Magnesite and dolomitic magnesite appear all around the walls of the east quarry, which has been extended 100 feet north into the hillside along a width of 60 feet and to a depth at the face of 30 feet. As judged by field tests, much of the rock at the back is of higher grade than that at the front, which is dolomitic.

The west quarry is an opening 70 by 50 feet and shows a 20-foot face at the back. The northwest half is massive magnesite, but the southeast side is mainly dolomite.

Crosby area

The Crosby deposit is located in the NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 8, (31-39) at about 3,600 feet above sea level. It lies near the head of a tributary of Deer Creek and is reached by an old branch road that leads up to the Double Eagle and Red Marble quarries.

This deposit trends northeastward and dips 45° NW. The mass is traceable for some 400 feet up the hillside northward, and the width is 125 feet.

Some small trenches constitute the quarry, which was opened in pink to red, finely crystalline magnesite. At the southwest end of the outcrop a gray, coarsely crystalline phase is cut by quartz veins in several places. The beds, 1 to 8 inches thick, are sharply separated by undulating surfaces. A sample of the reddish phase of the magnesite in the quarry is represented by analysis No. 32.

Red Marble area

Included in this area are three separate parts of the Stensgar dolomite, and the northeastern portion of the lower dolomite of the Deer Trail group. (See pl. 1.)

The most westerly outcrop of the Stensgar begins in the southwest corner of sec. 35, (31-38), from which it continues northeastward along the east slope of a spur that extends southward from Stensgar Mountain. It crosses the road to the Lookout, descends into a deep canyon, and follows for some distance along the canyon wall west of the Red Marble quarry. It dips steeply into the hillside throughout. It seems most likely that the dolomite continues beneath rubble and slope wash considerably farther north, even to the Davis and Midnight, and it is so mapped on plate 1. The outcrop lies between 4,000 and 4,500 feet above sea level.

The rock weathers light gray but has a light bluish gray color on the fresh surface. Much of it is fine-grained to dense, but the mass at the south end of the outcrop is considerably coarser and is magnesian. A number of samples were taken across the strike of the beds near the northeast corner of sec. 35. The analyses of those are given as Nos. 1-7. Analysis No. 18 is from the SW $\frac{1}{4}$ sec. 25.

The central outcrop includes the old Red Marble quarry. It forms a ridge trending slightly east of north in the southeast corner of sec. 24, then continues southward across a broad saddle and into a relatively shallow ravine in the NE $\frac{1}{4}$ sec. 25, (31-38). The total length of outcrop is some 4,000 feet and the width 450 feet. The north end forms the east side of a deep canyon toward which the beds dip at an angle of 45 degrees. The

south end lies on the wooded east slope of a southward-trending shallow ravine. The mass crops out at 3,500 feet on the north and reaches 4,000 feet above sea level at the side of the old Red Marble quarry.

Much of this rock mass from one end to the other is coarse and finely crystalline magnesite, of which some parts are reddish, pinkish, or white, with others showing gray spots on a cream-colored background. Some wedge-shaped masses of fine-grained dolomite occur along the east side of the outcrop, but these are small in comparison to the immense body of magnesite. On the west side there is an unusually even banding of coarse pink magnesite and wider fine bands of pale lavender. Field tests suggest that the more coarsely crystalline layers are a little higher grade than the finer phases. The parallelism of the banding and the bedding suggests that the bedding controlled the banding.

Samples collected along the outcrop of the Red Marble mass from north to south average 45.6 percent magnesium oxide and range from 0 to 1.4 percent calcium oxide. The analyses are listed as Nos. 53-55, 58, 61, 63, 66, 69, and 72.

The eastern band of Stensgar dolomite crops out at 3,900 feet above sea level in the NW $\frac{1}{4}$ sec. 30, (31-39), from which it extends northeastward diagonally down an eastern slope to Deer Creek at an elevation of 3,100 feet. It dips, like the other Stensgar outcrops just described, westward into the hillside. Much of the mass is covered by slope wash.

This band was considered by Jones^① as the lower dolomite in the Deer Trail group. It is here regarded as the Stensgar dolomite on the evidence presented in the foregoing section on Structure. This bed appears to be a potential source of magnesite. This may be the outcrop which Shedd^② has reported as containing magnesite of high grade.

Dolomite is exposed along the middle tributary of Deer Creek in sec. 31, (31-39). It lies on top of the lower quartzite in the Deer Trail group. The outcrop has not been followed continuously either way from the canyon, but since dolomite crops at several places along the strike, it is very probably continuous for three or more miles and has been so mapped.

This bed is mostly dark gray and a little coarser grained than the overlying Stensgar. Samples collected in sec. 31 show that it is magnesian, with the silica running from 20 to 30 percent. Analyses Nos. 11 and 12 give the chemical composition.

U. S. Magnesite area

The southernmost deposit of magnesite from which ore has been shipped is located west and north of Springdale, near the Cleveland mine road in the NW $\frac{1}{4}$ sec. 10, (30-38). The quarry is located at the head of a tributary of Camas Creek at 4,000 feet above sea level.

An area 125 by 100 feet has been uncovered close to the bottom of the Stensgar dolomite. Two outcrops of fine-grained dolomite on the hillside above the quarry appear to extend the thickness of the Stensgar to at least 300 feet. In 1917 the quarry was visited by Stone^③, who reports 38.41 percent magnesium oxide in the upper 40 feet and 40.90 percent magnesium oxide in the middle 18 feet of the quarry.

^① Jones, R. H. E., Geology and mineral resources of the Chewelah quadrangle: Washington Div. of Geology. Unpublished report, 1929.

^② Shedd, Solon, Cement materials and industry in the State of Washington: Washington Geol. Survey Bull. 4, p. 246, 1913.

^③ Yale, C. G., and Stone, R. W., Magnesite: U. S. Geol. Survey Mineral Resources 1918, pt. 2, p. 151, 1921.

Analyses of a number of samples taken in the quarry face in 1935 are given as Nos. 19, 27, 30, 31, 35, 37, 40, 41, 43-45, 47, 49-51, 56, 64, 67, 70, and 71. Several samples from an ore pile are included. Some high grade magnesite occurs in the quarry, but much of it is intimately intermixed with dolomite. Some of the material that appears to be good magnesite is actually high in calcium. The high silica samples are near a shear zone where talc or sericite indicate alteration by thermal waters. Several narrow quartz veins cut across the quarry and lower the grade of ore.

The dolomite is apparently faulted out to the northeast, since slate is encountered a short distance along the strike. Additional evidence includes slickensided blocks of quartzite on the hillside and a spring at the base of the outcrop. A thrust fault has therefore been drawn on the map at the base of the upper quartzite member of the Deer Trail group which presumably cuts out the Stensgar for 2 miles northeastward. (See pl. 1.) Magnesitic dolomite appears in old pits located 1,500 feet southwest of the U. S. Magnesite quarry 300 feet northeast of the summit on the Cleveland mine road (Analysis No. 14).

Scattered knobs of dolomite crop out around the Cleveland mine, but none of them were sampled. A band of dolomite 1,000 feet wide is recorded by Jenkins^① on data from underground workings. A bed of dolomite crops out in two gullies in this vicinity. One, poorly exposed and probably not more than 100 feet thick, is half a mile east of the U. S. Magnesite quarry where it lies above a westward-dipping bed of quartzite. The second, one and a quarter miles southeast of the U. S. quarry, was sampled (Analysis No. 15). Although the analysis shows the rock to be a magnesian dolomite, it is high in silica and corresponds to two other samples collected from the same bed 3 miles to the northeast and described under the Red Marble area.

Firminhac area

The Firminhac area includes three deposits, the Firminhac talc itself, one a mile to the southwest, and another half a mile west of the Firminhac.

The Firminhac talc is located in the SW $\frac{1}{4}$ sec. 15, (30-38), a quarter of a mile north of the Springdale-Hunters road, at 3,500 feet above sea level. The enclosing dolomite, mapped as the lower dolomite of the Deer Trail group, is about 100 feet thick and crops on a south slope where it dips into the hill at 20°. Where intruded by diorite the dolomite has been sheared, as revealed in an L-shaped trench. Wilson and Pask^② record a reported occurrence of "impure magnesite" as country rock in the deposit of talc. Samples show a decrease in magnesium away from the shear zone (Analyses No. 36 and 46). A mile southwest of the Firminhac the west end of the lower dolomite outcrop is opened by a small quarry. The 125-foot bed of dark gray, fine-grained dolomite dips 30°-40° north. Some small masses of dolomite crop at 4,000 feet elevation half a mile west of the Firminhac in the NE $\frac{1}{4}$ sec. 16, (30-38). Here a single bed of light blue dolomite has been separated by erosion into three segments, which, although nearly flat lying, show a dome structure for the group. The brown weathered surface shows an irregular relief pattern of chert nodules and veinlets.

^① Jenkins, O. P., Lead deposits of Pend Oreille and Stevens counties, Washington: Washington Div. Geology Bull. 31, p. 125, 1924.

^② Wilson, H., and Pask, J. A., Talc and soapstone in Washington: Am. Ins. Min. and Met. Eng., Contr. 99, p. 9, 1936.

C. F. Allen area

The region thus designated lies wholly in sec. 16, (30-38) and includes outcrops of dolomite for which the correlation is somewhat in doubt, although they are of necessity mapped as either Stensgar or lower dolomite of the Deer Trail group.

Outcrops of dolomite south of the west quarter corner of sec. 16 reveal the presence of a 325-foot bed, which strikes northeast and dips 45° - 50° northwest. The largest of this group of outcrops, 325 by 600 feet, is at the head of a ravine at the west side of sec. 16. This fine-grained gray dolomite is crossed by irregular veins of coarser carbonate filling fractures. Analyses Nos. 42, 57, and 68 show that this mass is magnesitic in some portions.

A quarter of a mile northeast of the bed just described are two small outcrops of bluish dolomite. Each shows a stratigraphic thickness of a little more than 150 feet and may be the same bed, repeated by a strike fault. It is even more probable that the eastern mass is a part of the Stensgar described above, and these are mapped as one short belt of Stensgar. On the other hand the difference in thickness and color of these two masses is ample to raise doubt as to this correlation. On these features the central outcrops would be correlated with some still further to the northeast in the same section.

Small knobs of dolomite, tentatively correlated as the lower dolomite of the Deer Trail group, are south of the center of sec. 16. Because of the low north dip this relatively unimportant mass is mapped as a fairly wide band.

Turk area

This region includes that part of the magnesite belt lying between the Springdale-Hunters road and the north boundary of the Spokane Indian Reservation. Within this 7-mile strip there has so far been discovered but one promising area of magnesite, although the following section includes a description of a number of other deposits of carbonate rocks which have been examined.

The Turk magnesite lies partly in sec. 1, (29-37) and partly in sec. 36 to the north. This is the largest body of magnesite so far reported in that portion of the magnesite belt southwest of the Red Marble deposit. This topographically prominent magnesite body crops out about 3,000 feet above sea level and is covered by alluvium at the north. The ore body is at least 1,500 feet long, nearly 325 feet wide at the north, and at least 200 feet wide at the south end. While the western limit is not easily determined, the mass seems to narrow southward, giving a somewhat wedge shape to the whole.

The ledge strikes N. 10° E., with dips from vertical to 80° SE., showing a slight overturning in that direction. Structural data from outcrops elsewhere in the Turk area provide a basis for placing a strike fault somewhat east of the Turk ledge.

The coarse-grained texture is more uniformly maintained in this mass than elsewhere throughout the whole of the magnesite belt. This mass has been prospected by tunnels driven across the 300-foot ore body near each end. Channel samples taken in a number of places both at the north and south ends of the ledge show a uniformly high magnesium content. Those at the north are reported as analyses 77, 78, 79, and 80, while the two at

the south are numbers 73 and 74. There seems little doubt that the whole width of the ledge is high-grade magnesite.

An area that is mapped as underlain by Stensgar dolomite lies in secs. 19, 20, and 30, (30-38), and part of sec. 36, (30-37). This area extends 3 miles in a northeasterly direction and includes a divide estimated to be 3,000 to 3,500 feet above sea level. Except for quartzite, outcrops are few and small.

The Stensgar forms a small knob in the NW $\frac{1}{4}$ sec. 20 southwest of the Springdale-Hunters road. Well exposed at the north, the extension of this mass southwestward into sec. 30 is only indicated by very small outcrops and rubble. In sec. 19 the belt is cut by a stock of biotite granite with the development of masses of lime silicates. Throughout the rest of the belt the rock is a medium to coarse marble. Samples along this part are plain dolomite, only the one taken at the northernmost outcrop showing magnetitic variation (Analyses No. 26, 28, 33, 34, 38, 48, 52, and 59).

A thin-bedded cherty dolomite is exposed around a spring west of the center of sec. 30, (30-38). Two small outcrops 75 to 100 feet apart on either side of the spring furnish the only evidence of a dolomite mass. The mass east of the spring is cherty, thin bedded, and greatly contorted. The texture of this part is fine grained to dense, though the mass west of the spring is cut by veinlets of coarse texture. None of the material here appeared to be magnetitic, and no samples were taken for analysis.

A 6-foot pit partly filled on the divide close to the SW corner of sec. 30 shows dolomite, presumably the Stensgar, was encountered, but no magnesite appears on the dump.

A small outcrop of medium-grained dolomitic marble was found approximately in the NE $\frac{1}{4}$ sec. 36, (30-37). This is southwest of the divide. A few other small exposures in this general vicinity are also dolomitic marble.

Argillaceous dolomite crops out in the SW $\frac{1}{4}$ sec. 36, (30-37). Some loose fragments show parts of this mass are low-grade magnesite. Although apparently unimportant, this mass may continue beneath the valley fill and should not be overlooked in the search for high-grade magnesite.

Coarse granular white dolomitic marble crops out in two small knobs and is exposed in a partly caved tunnel approximately in the NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 36, (29-37). This is immediately east of the bottom of a broad ravine which leads southwestward.

Along the new road in the SW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 36 is exposed some 325 feet of granular dolomitic marble trending about N. 20° E., with nearly vertical dip. This is overlain by a greenish argillite on the west. The east side of the outcrop is intruded by a medium-grained granitic stock. This marble, texturally identical to the magnesite across the valley to the southwest, shows less cohesion when weathered, so that large lumps often crumble when squeezed in the hand. None of this mass appears to be magnesite. Although the continuity of the bed cannot be seen along the road, it grades to a calcareous slate on the east above the granite contact.

About an eighth of a mile southeast of the outcrop just mentioned is a hundred-foot band of carbonate rock which extends for over 2 miles southward across sec. 1 and into sec. 12, (29-37). This is mapped as undifferentiated limestone and shows by analyses Nos. 17, 23, and 25 both unusually pure calcium carbonate and high-grade magnesite.

At the extreme south end of the Turk area the Stensgar dolomite has been found in the operations of the Queen and Seal mine near the center of sec. 11, (29-37), about 4,000 feet above sea level. Only one loose fragment of what was apparently magnesite was picked up, and it appears that in this region the Stensgar is a normal dolomite. There are a few outcrops of dolomitic marble along the road south of the Queen and Seal property, and a 200-foot outcrop in sec. 14, (29-37) east of the Aichan-Bee mine is apparently also all dolomite.

Spokane Indian Reservation area

The Stensgar dolomite is very poorly exposed within the limits of the Spokane Indian Reservation. It is well revealed, however, in the Orazada workings in the SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 27, (29-37). The pinkish dense dolomite appears to be about 300 feet wide, although faulting makes this figure subject to correction. Field tests with acid fail to reveal any magnesite.

Dolomite crops out southwest of the Orazada in the NW $\frac{1}{4}$ sec. 34, where a few square feet of dark gray dense rock constitute the only suggestion of the extension of the Stensgar formation into this area. About a mile farther south the rocks of the magnesite belt are overlain and entirely concealed by the Jerome andesite of Tertiary age, and the intervening area appears to show no evidence of any magnesian rocks.

CHEMICAL ANALYSES

The chemical data of the following table were submitted by H. A. Doerner, in charge of the Pullman Station, U. S. Bureau of Mines, who kindly arranged to have the analyses run under his supervision by Fred G. Mehl.

Analyses were made of 81 samples collected from 20 localities along the magnesite belt. Most of the samples represent the Stensgar dolomite, but some have been collected from the lower dolomite shown on the maps accompanying this report.

Analyses have been made of magnesite and dolomite from the Woodbury, Pheonix, Crosby, Red Marble, U. S. Magnesite, and Turk deposits, all of which are designated by name on the maps. Analyses from localities less well known are located by section, township, and range only.

With the exception of the Turk deposit, the analyses represent only lump samples. The several samples from the Red Marble were taken along the length of outcrop, most of them north of the quarry. One sample from each of three small outcrops was taken from the south end of the Red Marble.

Eighteen samples were taken of the U. S. Magnesite quarry, four of them from an ore pile on the quarry floor.

"Ignition loss" in the table represents mainly carbon dioxide, and "Insoluble" is mainly silica. The column labeled experimental (Expr.) is magnesium oxide determined by direct precipitation. Calculated (calc.) magnesium oxide percentages have been obtained by subtraction of the combined percentages of the other items from 100 percent. This value is always larger than that of the experimental.

It will be noted that only 10 of the 81 analyses show true dolomite. One, No. 25, is limestone, and the others are magnesite, high-calcium or dolomitic magnesite, and dolomite with a slight excess of magnesium. More magnesium is available in many of the dolomites than can be satisfied by the available carbon dioxide.

TABLE OF ANALYSES

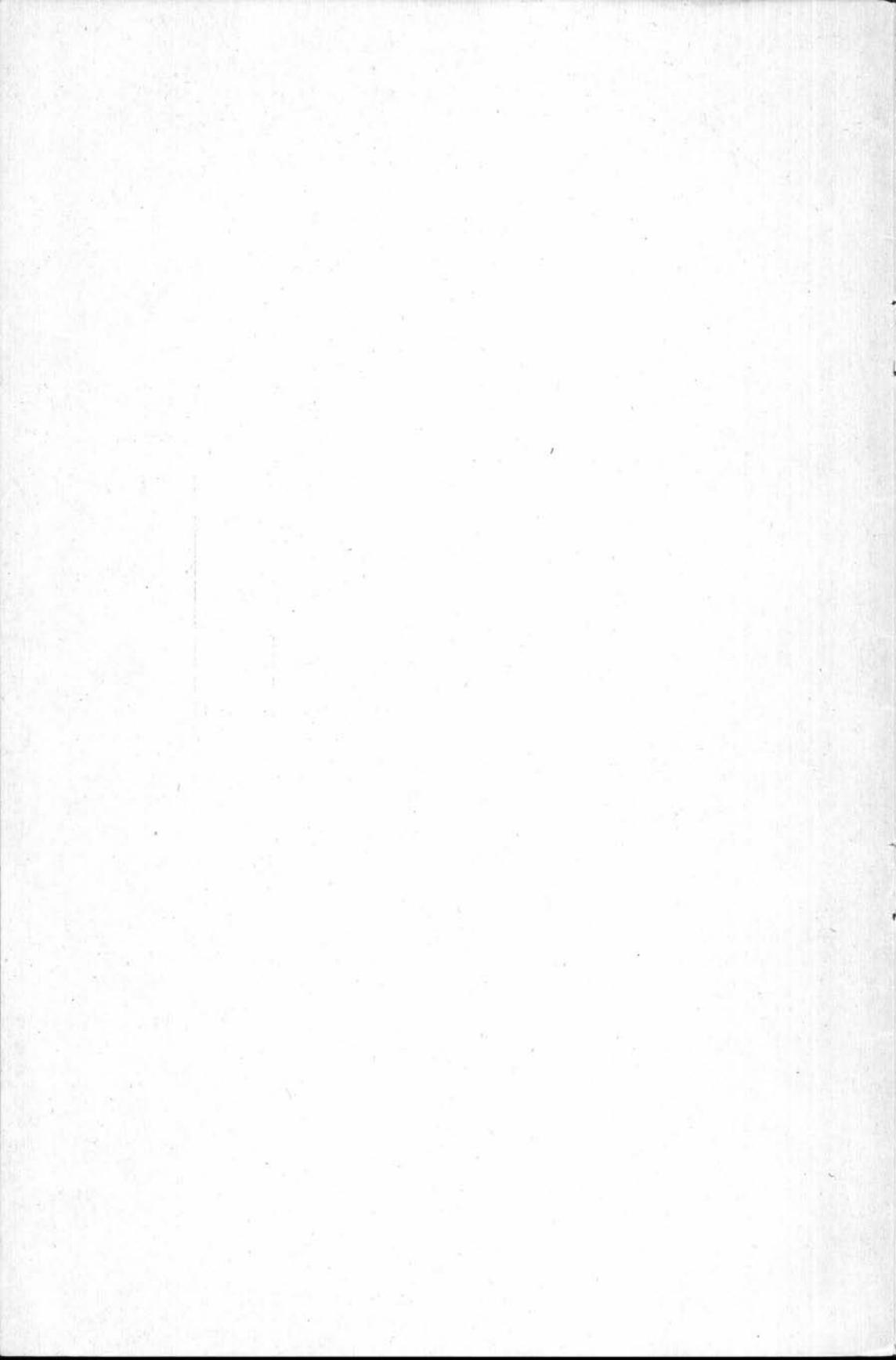
No.	Location	Ignition loss	Insol.	Al ₂ O ₃ + Fe ₂ O ₃	CaO	Expr. MgO	Calc. MgO
1	T. 31 N., R. 38 E. sec. 35	43.1	6.9	1.0	27.3	.....	21.8
2	sec. 35	45.3	1.5	1.4	29.4	.....	22.3
3	sec. 35	44.7	3.1	1.6	29.0	.....	21.2
4	sec. 35	42.3	8.1	1.8	27.5	.....	20.3
5	sec. 35	45.4	3.3	1.4	25.5	.....	24.4
6	sec. 35	45.3	2.2	1.4	29.5	.....	21.6
7	sec. 35	43.7	4.6	2.1	28.9	.....	20.7
8	sec. 24	45.3	0.9	0.8	20.9	.....	24.7
9	sec. 36	45.9	0.9	1.6	20.6	.....	31.0
10	sec. 36	40.0	10.6	3.9	18.7	.....	26.8
11	T. 31 N., R. 39 E. sec. 31	29.9	31.2	3.7	14.6	.....	20.6
12	sec. 31	33.3	22.8	3.9	17.4	.....	22.6
13	sec. 32	41.0	9.3	2.7	19.2	.....	27.8
14	T. 30 N., R. 38 E. sec. 10	36.7	17.2	2.2	18.8	.....	25.1
15	sec. 11	35.9	19.4	3.9	16.6	.....	24.2
16	sec. 21	37.7	16.9	3.3	17.1	.....	25.0
17	T. 30 N., R. 37 E. sec. 36	39.3	8.1	1.6	17.5	.....	33.5
18	T. 31 N., R. 38 E. sec. 25	43.8	3.8	2.8	28.2	20.0	21.4
19	T. 30 N., R. 38 E. sec. 10	48.2	3.6	1.8	11.9	35.4	34.5
20	T. 31 N., R. 39 E. sec. 1	47.9	2.6	1.9	3.6	41.4	43.9
20-A	T. 31 N., R. 39 E. sec. 3	44.0	4.8	1.9	28.4	20.4	20.9
22	sec. 1	46.8	1.2	1.5	24.9	25.5	25.6
23	T. 30 N., R. 37 E. sec. 36	43.5	6.3	2.2	1.4	45.1	46.6
24	T. 32 N., R. 40 E. sec. 31	50.8	1.7	1.5	27.0	19.6	19.0
25	T. 30 N., R. 37 E. sec. 36	32.5	21.1	2.5	41.7	0.6	2.2
26	T. 30 N., R. 38 E. sec. 19	43.6	2.9	1.0	29.9	21.1	22.5
27	sec. 10	50.3	2.3	1.3	1.0	44.9	45.1
28	sec. 19	42.6	7.3	1.5	31.5	16.8	17.1
29	T. 31 N., R. 39 E. sec. 3	49.1	4.8	1.2	1.7	42.5	43.2
30	T. 30 N., R. 38 E. sec. 10	41.3	14.0	3.2	4.3	36.8	37.2
31	sec. 10	43.9	10.8	2.6	2.8	39.4	39.9
32	T. 31 N., R. 39 E. sec. 18	48.9	4.2	2.3	0.4	43.6	44.2
33	T. 30 N., R. 38 E. sec. 19	47.5	0.5	1.2	25.7	24.7	25.1
34	sec. 19	47.6	2.0	1.1	14.9	33.2	35.0
35	sec. 10	50.0	3.6	1.1	1.6	43.0	43.7
36	sec. 15	45.8	1.5	2.2	27.5	22.1	23.0
37	sec. 10	49.3	3.8	1.2	2.2	42.8	43.5
38	T. 30 N., R. 38 E. sec. 19	43.0	4.5	0.7	30.0	21.6	21.8
39	T. 31 N., R. 38 E. sec. 25	45.1	3.9	0.9	29.3	22.0	20.8
40	T. 30 N., R. 38 E. sec. 10	45.9	3.3	2.2	23.2	24.9	25.4
41	sec. 10	48.5	5.6	1.1	1.0	42.9	43.8
42	sec. 17	45.9	2.5	1.0	26.2	23.8	24.4
43	sec. 10	47.0	1.8	1.3	20.2	28.3	29.7
44	sec. 10	35.0	24.8	1.9	21.4	16.6	16.9
45	sec. 10	27.3	35.5	4.3	14.9	18.0	18.0
46	sec. 15	47.7	1.5	1.2	18.8	29.4	30.8
47	sec. 10	28.3	33.5	4.0	15.3	18.3	18.9
48	sec. 19	46.5	1.4	1.4	21.9	25.3	28.8
49	sec. 10	47.0	4.9	2.1	6.7	38.6	39.3
50	sec. 10	43.9	6.2	1.1	24.8	22.1	24.0
51	sec. 10	45.0	2.5	2.3	27.9	.....	22.3
52	sec. 19	45.2	3.6	0.4	29.1	20.2	21.7

TABLE OF ANALYSES—Concluded

No.	Location	Ignition loss	Insol.	Al ₂ O ₃ + Fe ₂ O ₃	CaO	Expr. MgO	Calc. MgO
53	T. 31 N., R. 38 E.						
54	sec. 24	50.1	2.3	1.4	0.5	44.1	45.7
55	sec. 24	50.5	2.3	0.8	0.1	45.0	46.3
	sec. 24	51.0	1.5	0.6	1.4	44.9	45.5
	T. 30 N., R. 38 E.						
56	sec. 10	31.0	37.9	1.3	3.0	25.9	26.8
57	sec. 17	46.8	0.9	0.8	29.3	20.9	22.2
	T. 31 N., R. 38 E.						
58	sec. 24	48.1	5.4	1.0	1.1	43.3	44.4
	T. 30 N., R. 38 E.						
59	sec. 19	41.0	5.8	1.8	29.8	21.9	21.5
	T. 31 N., R. 39 E.						
60	sec. 1	47.0	3.5	1.6	16.9	30.0	31.0
	T. 31 N., R. 38 E.						
61	sec. 24	50.7	2.2	0.6	0.1	45.0	46.4
	T. 31 N., R. 39 E.						
62	sec. 1	46.5	1.3	1.4	28.8	21.4	22.0
	T. 31 N., R. 38 E.						
63	sec. 24	49.3	4.5	1.1	0.1	44.0	45.0
	T. 30 N., R. 38 E.						
64	sec. 10	46.0	2.0	1.6	27.8	22.0	22.6
	T. 31 N., R. 39 E.						
65	sec. 1	46.1	1.9	2.4	26.5	22.4	23.1
	T. 31 N., R. 38 E.						
66	sec. 24	49.9	3.1	0.9	0.6	44.3	45.5
	T. 30 N., R. 38 E.						
67	sec. 10	50.3	2.3	1.1	0.8	44.4	45.5
68	sec. 17	43.2	6.3	2.6	26.8	19.6	21.1
	T. 31 N., R. 38 E.						
69	sec. 24	50.8	1.6	0.7	0.5	45.2	46.5
	T. 30 N., R. 38 E.						
70	sec. 10	47.2	5.4	1.6	6.0	38.8	39.8
71	sec. 10	48.2	5.6	1.0	0.7	42.8	44.5
	T. 31 N., R. 38 E.						
72	sec. 24	50.4	2.3	0.9	0.3	44.7	46.1
	T. 29 N., R. 37 E.						
73	sec. 1	46.5	4.7	0.9	0.8	45.7	47.1
74	sec. 1	46.4	5.0	0.9	0.6	46.0	47.1
75	sec. 1	40.9	3.2	1.6	29.2	24.1	25.2
76	sec. 1	43.7	1.5	1.8	28.6	22.9	24.4
	T. 30 N., R. 37 E.						
77	sec. 36	45.3	5.8	2.4	0.6	45.8	46.0
78	sec. 36	45.4	5.2	1.5	3.1	43.5	44.6
79	sec. 36	44.5	6.3	2.1	1.6	45.0	45.3
80	sec. 36	42.2	8.6	2.5	0.4	46.1	46.2
81	sec. 36	44.5	1.9	1.0	29.4	20.8	23.2

Tark

Tark



R. 38 E.

116°00'

R. 39 E.

117°50'

R. 40 E.

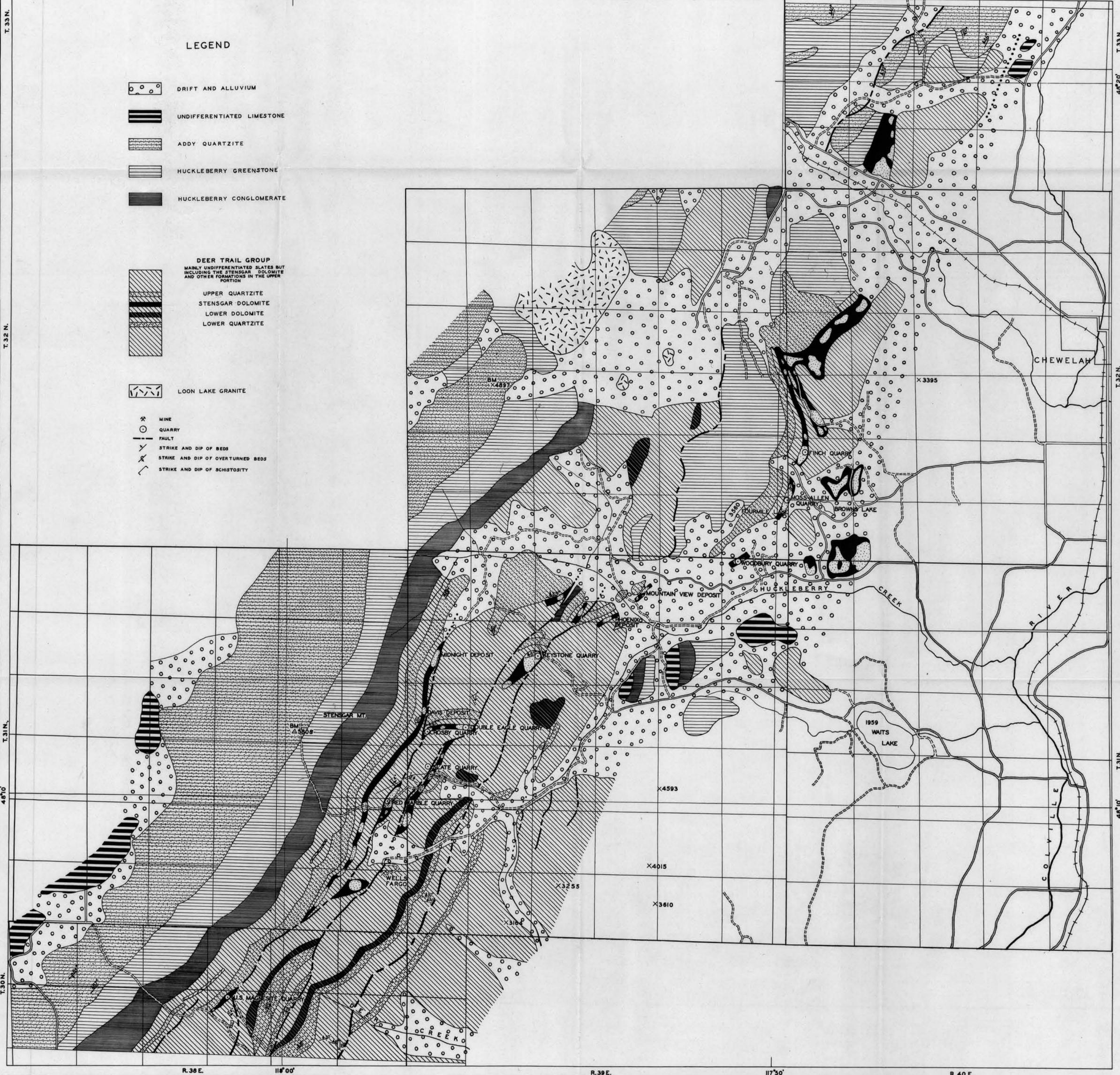
LEGEND

-  DRIFT AND ALLUVIUM
-  UNDIFFERENTIATED LIMESTONE
-  ADDY QUARTZITE
-  HUCKLEBERRY GREENSTONE
-  HUCKLEBERRY CONGLOMERATE

- DEER TRAIL GROUP**
 MAINLY UNDIFFERENTIATED SLATES BUT INCLUDING THE STENSGAR DOLOMITE AND OTHER FORMATIONS IN THE UPPER PORTION
-  UPPER QUARTZITE
 -  STENSGAR DOLOMITE
 -  LOWER DOLOMITE
 -  LOWER QUARTZITE

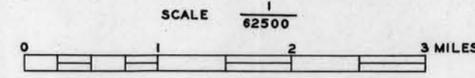
-  LOON LAKE GRANITE

-  MINE
-  QUARRY
-  FAULT
-  STRIKE AND DIP OF BEDS
-  STRIKE AND DIP OF OVERTURNED BEDS
-  STRIKE AND DIP OF SCHISTOSITY

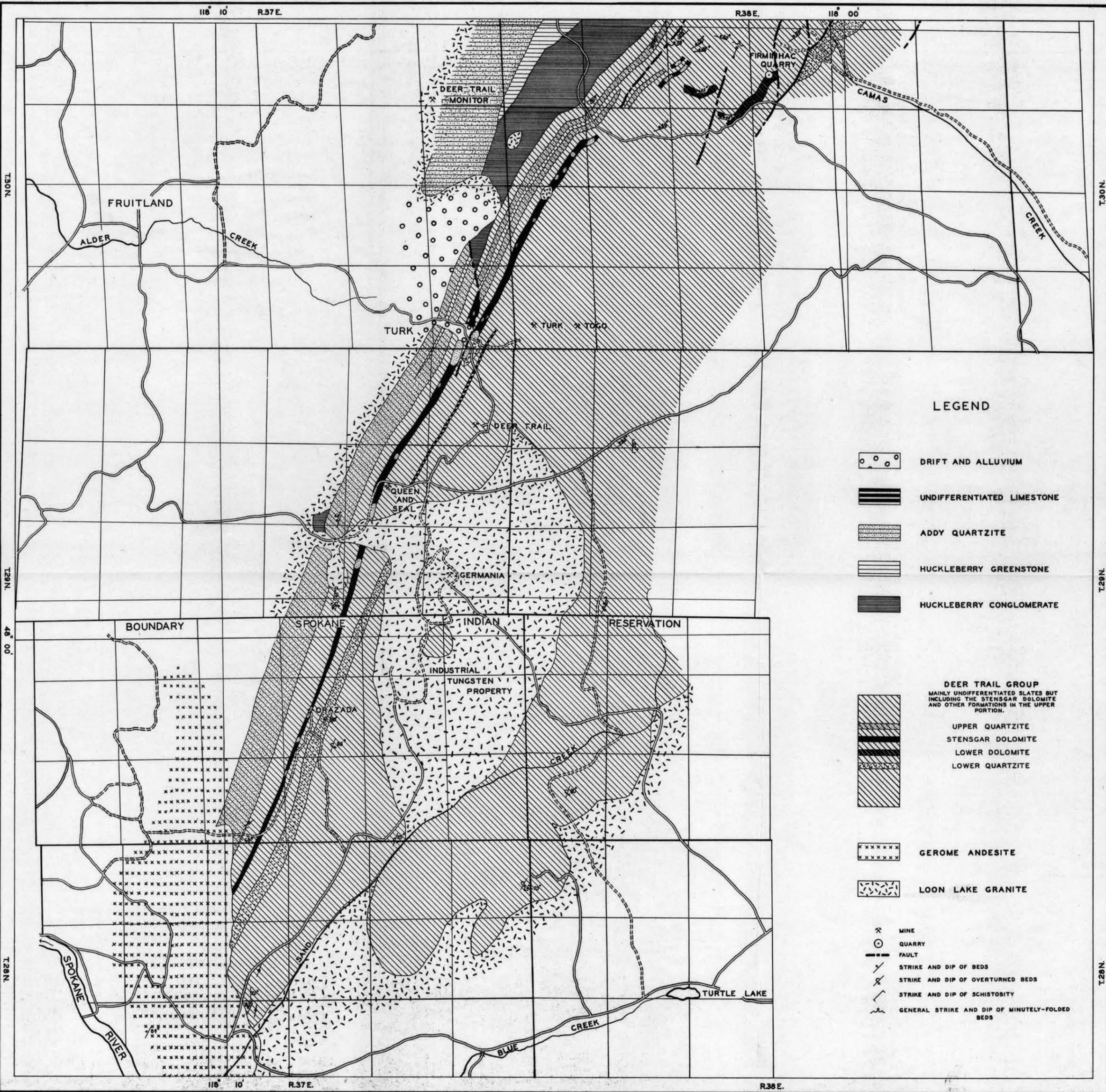


BASE ADAPTED FROM
 STATE DEPARTMENT OF HIGHWAY'S
 STEVENS COUNTY MAP

NORTH HALF OF THE MAGNESITE BELT
 STEVENS COUNTY WASHINGTON



GEOLOGY BY W.A. BENNETT
 IN PART ADAPTED FROM STUDIES
 BY C.E. WEAVER 1920
 AND R.H.B. JONES 1929



LEGEND

- DRIFT AND ALLUVIUM
- UNDIFFERENTIATED LIMESTONE
- ADDY QUARTZITE
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- LOON LAKE GRANITE

- MINE
- QUARRY
- FAULT
- STRIKE AND DIP OF BEDS
- STRIKE AND DIP OF OVERTURNED BEDS
- STRIKE AND DIP OF SCHISTOSITY
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