GEOLOGY OF THE SUGAR PINE AREA

Madera County California

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ABSTRACT

The Sugar Pine area includes nine square miles in northern Madera County, on the western slope of the Sierra Nevada.

Intrusive rocks of the Sierra batholith surround a central roof pendant and associated minor bodies of strongly folded and metamorphosed Paleozoic sediments. The main mass of the intrusive is tonalite, petrographically notable for the selective albitization of its potash feldspar. It contains an abundance of small dark crystalline autoliths. Isolated areas of diorite and gabbro and many small pegmatite and aplite dikes complete the Jurassic intrusive sequence.

The metamorphic rocks are mainly quartzite, with some schist and calcareous beds, the last giving rise to three distinct metamorphic rock types. The margin of the pendant is locally marked by a zone of partial assimilation and reconstitution.

Post-Jurassic fracturing, perhaps involving some displacement, serves as structural control for several springs in the area.

Tungsten mineralization is associated with one of two large pegmatites intruding the central pendant. Scheelite occurs disseminated in lenses of tactite, a restricted facies of the metamorphosed calcareous beds. Some tactite lenses carry over one per cent of scheelite, but the small total volume of ore makes the exploitation of the deposit impractical.

Contents

INTRODUCTION

Purpose of the report

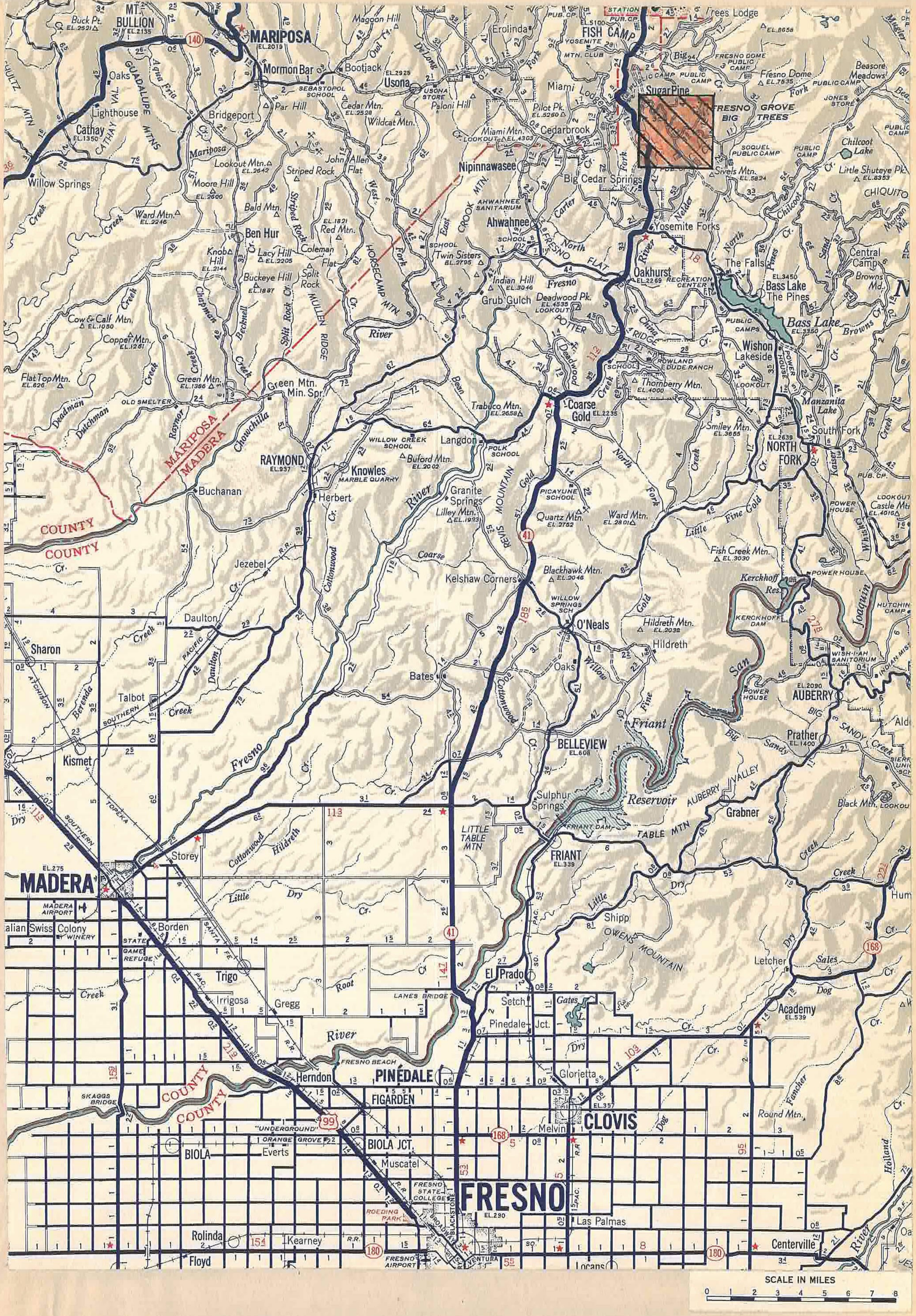
The investigation described in this report was undertaken to determine the extent and economic possibilities of the tungsten deposits on the southeast slopes of Wells Mountain, and to prepare a reconnaissance map of their geologic environment.

Location and size of area

The village of Sugar Pine is located in northern Madera County, California, on the west slope of the Sierra Nevada (see Index Map, page 2). The area investigated comprises nine square miles southeast of Sugar Pine, including Sections 1, 12 and 13 of Township 6 S, Range 21 E, and Sections 5, 6, 7, 8, 17 and 18 of Township 6 S, Range 22 E, Madera baseline and meridian. The northern boundary of the area lies 3 1/4 miles south of the southern extremity of Yosemite National Park.

The main Fresno-Yosemite highway runs through the southwest corner of the area. At a point about 55 miles northeast of Fresno a paved branch road, three quarters of a mile in length, runs from the highway to the village of Sugar Pine. A few unimproved roads traverse the region east of the highway.

By Act of Congress the land is included in the Sierra



North-central Madera County, California

INDEX MAP

National Forest, except for a few isolated prior private holdings, including homes in and around Sugar Pine, and 360 acres near the center of the area owned by Dr. C.E. Wells and the Arthur Fleming Trust.

History

The area bears abundant marks of a former lumber industry. The village of Sugar Pine, now residential, was once the site of a lumber mill. The roads of the region, several of which were originally railroads, were built for the transportation of logs. Adjacent areas were worked for placer gold in earlier days. Lode mining has been restricted to a few unsuccessful prospecting ventures. At the present time lumbering activity is curtailed by protective restrictions in the National Forest. The region is now a recreational area and an open stock range.

Previous geologic work

No systematic study of the geology of this area has previously been recorded, and references to the region are scanty and generalized. A deposit of molybdenite near Sugar Pine is reported by McLaughlin and Bradley, but no

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McLaughlin and Bradley XIV Rep. of State Mineralogist Cal. Min. Bureau 1914, p.559

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ore was mined. The deposit was not located by the author, unless it is in the pegmatite on the southeast side of Wells Mountain, where a prospect pit contains traces of molybdenite.

Present Geologic Investigation

The entire nine square miles was mapped by pace and Brunton compass traverses on a scale of 1 inch = 1087 feet, using a base map made from an approximately tenfold enlargement of the U.S.G.S. topographic sheet of the Mariposa Quadrangle. In addition a small area in Section 7, in the vicinity of the tungsten mineralization, was surveyed and mapped on a scale of 1 inch = 100 feet.

It was found that the location of points by pace and compass traverses resulted in greater accuracy than did reliance on the enlarged topographic map. Therefore an attempt was made to map a self-consistent network of roads, tied in to three Forest Service section markers, located at the north and south quarter corners of Section 7, and 29 chains east of the northwest corner of Section 6. A fourth basis of reference was obtained from the original survey notes of the main highway in Section 13. Cross - country traverses were tied in to the road traverses at one or both ends. The topographic map has been modified wherever it conflicts with the observed facts.

At the Tin Bucket tungsten claims, shown in Plate III, a transit line was run from the county survey stake at the south quarter corner of Section 7, northward to the west end of the claims and thence northeastward through the claims. Important intermediate points were established with a plane table, and the detailed geology then mapped by pace and compass from this baseline. A portable ultra-violet lamp was used to estimate the distribution of scheelite.

Five weeks were spent in the field during June and July of 1942. The petrographic work was done and the writing of the report completed during the following winter at the California Institute of Technology.

Acknowledgements

The author is most grateful to Dr. and Mrs. C.E. Wells of Mirimichi Ranch, whose generous hospitality and kindness made the field season a real pleasure.

Dr.H.J. Fraser and Dr. Ian Campbell of the California Institute of Technology supervised the work. Their advice and assistance throughout is much appreciated. Dr. Fraser spent several days with the author in the field.

Credit is due to Mr.Robert Nichols of Oakland, who assisted with the plane table. Mr.Dean Cook of Sugar Pine and the California Public Roads Administration were most helpful in ascertaining certain locations as reference points for the map.

PHYSICAL CONDITIONS

The Sugar Pine area lies on the western slope of the Sierra Nevada at an average elevation of 5000 feet. The minimum altitude is 3300 feet and the maximum 6800 feet. Summer weather is warm and dry, though the temperature rarely rises above 90°F. On this side of the Sierra the maximum precipitation, from 40 to 60 inches annually, occurs at about this altitude, affording optimum conditions for vegetation. Deep snow covers the region in winter, usually remaining until May.

The area is drained on the east by Alder Creek and Redwood Creek, and on the west by Sugar Pine Creek and the Lewis Fork of the Fresno River. Several tributary streams on the west side originate in springs, the significance of which is discussed below.

Relief is considerable, and slopes are fairly steep. The soil cover is extensive, but thin and patchy, and contains much slide material. The region is for the most part thickly forested with pine, fir, and cedar, though oak trees are seen in the lower flats. Treeless slopes are covered with buckthorn, manzanita, and other scrub. Many magnificent sequoia trees, making up the Nelder Grove, are scattered over the northeast section.

STRATIGRAPHY

Introduction

The stratified rocks of the area occur as pendants or inclusions in the Sierra batholith. The sedimentary section is mostly quartzite, with some interbedded schist, and occasional zones of altered limestone. The attitude of the beds, though locally irregular, shows an average strike of N 10°E, and a very steep dip, which is more commonly east than west.

The stratigraphic thickness of the section is unknown, but does not exceed 7000 feet and is probably much less than this figure. The whole stratified series has been affected by folding and regional metamorphism, and near the igneous contacts the rocks have been further metamorphosed by the intrusion. No fossils were found, but the intrusion of the beds by the Jurassic Sierra batholith indicates their age to be pre-Jurassic. A broad belt of sediments beginning a few miles northwest of the Sugar Pine area has been assigned to the Mississippian by H.W. Turner and others. It is part of a diverse Paleozoic series found throughout the central and northern Sierra Nevada to which the term "Calaveras formation" is somewhat loosely applied. Many parts of the Calaveras are dominantly quartzitic, and it is likely that the rocks of the Sugar Pine area belong in the same series, and therefore are of Late Paleozoic age.

Division of the formation into members is not practical. The tracing of individual beds is prevented by discontinuity of outcrop, and in the few cases where unique beds suitable for marker horizons occurred, these were seen in only one or two localities. Discussion of stratigraphy will therefore be divided into three sections, dealing with quartzite, schist, and calcareous rocks, recognizing that these terms do not refer to stratigraphic units, and that gradations occur between them.

Quartzite

Quartzite in varying degrees of purity makes up about 65 per cent of the section. The characteristic outcrop is colored dark by surface stains, and appears well stratified. Thickness of bedding is irregular, from an inch to several feet, though finely laminated or very massive beds are rarely found. Granularity varies from 1.5 mm. to 0.03 mm. Gray-green chert-like beds occur locally. The dominant colors of the fresh rock are gray-green and gray-blue, though dark gray and even pink facies are also seen. The coarsest quartzite is colorless and vitreous, while that of medium grain size frequently contains sericite, and grades into quartz schist.

Turner has suggested that much of the quartzite in

Turner, H.W.   U.S.G.S. An.Report XIV part 2, p.435

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the Calaveras was formed by silicification of shale, and should be called phthanite. Turner does not state whether he considers the added silica to be hydrothermal in origin. It is possible that some of the rocks near the borders of the pendant contain added silica derived from the intrusive magma, but no general decrease in silica was observed away from the igneous contacts.

The quartzite shows few contact metamorphic effects. Local increases in grain size near the intrusive might be ascribed to recrystallization at high temperatures, though aphanitic quartzite is also common in the vicinity of the contact. The quartzite is eroded mainly by the breaking out of angular chunks following the weathering out of interbedded schist. Typical outcrops are to be seen on the ridge between Alder Creek and West Alder Creek, directly south of the upper road.

Schist

About 30 per cent of the section is made up of schist, which is interbedded with quartzite to a greater or lesser degree throughout the formation. Resistance to erosion is roughly proportional to quartz content, and the highly micaceous varieties are soft and easily weathered. Three different mineralogical types are distinguished; quartz sericite schist, sericite schist, and hornblende schist, the last represented by a single outcrop. These rocks are the result of metamorphism of siltstone and sandy shale.

Quartz sericite schist

This is the predominant type of schist; its less micaceous facies grade into quartzite. It is usually dark colored, frequently gray-blue, and almost as hard as quartzite. Schistosity is rudely developed parallel to the regional strike. The sericite, which makes up roughly 10 per cent of the rock, is generally evenly disseminated, and not concentrated along bedding planes. However, in the northeast part of the area there are lenses, some tens of feet in length, composed largely of coarse grained biotite or muscovite.

The quartz sericite schist is best exposed on the ridge south of the summit of Wells Mountain.

Sericite schist

The sericite schist is restricted in its occurrence, and would be useful as a marker bed in detailed mapping. The rock is fine grained, soft, even-textured, and of a blue-gray color. It appears to be composed almost wholly of sericite. It is best exposed in the west side of the upper quarry in the southwest corner of Section 6, where it is about 60 feet thick. An outcrop on the road 1500 feet to the north is probably the same bed.

Hornblende schist

A bed of hornblende schist, four feet thick, is exposed for about 25 feet near the top of the southern knoll of Wells Mountain. The hornblende, in dark green euhedral chunky prisms averaging 3 mm. in length, is crudely lineated parallel to the bedding, and makes up 25 per cent of the rock. The matrix is fine grained quartz and diopside, with a trace of andesine. In thin section the hornblende crystals are seen to be full of quartz and diopside inclusions, and to have ragged edges. They are clearly metacrysts. The rock was probably formed by recrystallization of a sediment rich in ferromagnesian minerals.

Calcareous rocks

This category includes all calcareous stratified rocks, whether derived from true limestones or calcareous clastics. Though making up only about 5 per cent of the section, this group is the most important economically, because it is the host for tungsten mineralization.

Three lithologic types were recognized, wollastonite rock, granulite, and tactite. The first and last are of distinctive appearance, and their outcrops are indicated on the areal map. The granulite is difficult to distinguish from fine grained quartz sericite schist in the field, and it was not mapped as a separate unit. The calcareous beds are typically lenticular.

Wollastonite rock

This is a white medium grained rock of fibrous texture, easily recognized in outcrop by its differential weathering and solution grooves. It is found in the middle of the area as a discontinuous bed about 40 feet in width, paralleling the regional strike. A similar stratum, 90 feet in thickness, occurs in the small body of metamorphic rocks in Section 17.

The wollastonite, which is locally well lineated parallel to the bedding, occurs in blades 1 mm. in length, making up from 30 per cent to 60 per cent of the rock, in a groundmass of very fine grained colorless diopside. Small amounts of idocrase and calcite are also present, the latter in cross-cutting veinlets.

This rock is not found adjacent to igneous contacts. It is believed to represent an early stage in the silication of limestone. The relative proportions of original and introduced silica are unknown. No quartz was seen in thin section.

Granulite

The granulite is a dark, very fine grained, homogeneous rock, resistant to weathering, and having schistosity roughly parallel to its bedding. Bedding is shown in places by minor variations in grain size and color. In outcrop the granulite resembles much of the quartz sericite schist, and therefore its distribution and abundance are not accurately known. It is estimated to compose less than 5 per cent of the sedimentary section. The thin sections studied were taken respectively 180 feet southeast and 900 feet north of the nearest igneous outcrop, the Tin Bucket pegmatite in Section 7. Similar rock was seen adjacent to the pegmatite.

The granulite is made up of about 80 per cent anhedral quartz and diopside, having an average grain size of 0.04 mm., with 10 per cent of even finer grained magnetite and pyrite. The pyrite is occasionally found in larger subhedra. The remaining 10 per cent of the rock consists of hornblende and anhedral cordierite in varying proportions. Bedding is shown in thin section by thin lenses of coarser grained quartz. The granulite is completely recrystallized, and probably represents the silication of a more dolomitic facies than does the wollastonite rock.

Tactite

The name tactite is applied to a massive garnet-diopside rock, with some quartz, found only in the immediate vicinity of igneous contacts. Where tactite is in contact with tonalite at the borders of the pendant it is pale colored, relatively opaque, anhedral, and lacking in ore minerals. Little or no quartz is present.

Tactite of quite different texture is found in pits at the north and south ends of the Tin Bucket pegmatite, in Section 7. It is well crystallized, having brown dodecahedral garnets up to 3 mm. in diameter, bright green diopside and clear quartz. Scheelite and chalcopyrite are disseminated locally. No bedding or lineation is apparent. Garnet, of the variety grossularite, makes up 40 per cent of the rock. It is pale pink in thin section, euhedral, and invariably isotropic. Stubby subhedral diopside crystals, about 0.4 mm. long, average 30 per cent. The remainder is mainly clear quartz, in large anhedra.

This tactite is the end product of the silication of an original limestone. The addition of magmatic silica is indicated by the fact that the ratio of SiO_2 to CaO + MgO is 2.2, double that prevailing in the wollastonite facies, which itself may have an indeterminate amount of introduced silica. Iron, present in appreciable quantity in the diopside of the tactite, represents a further contribution by the magma.

In the small area of metamorphic rocks in Section 17 there is a 30 foot section of beds which appear to be a transition between wollastonite rock and true tactite. Bedding is well preserved. The rock contains 13 per cent wollastonite, together with garnet, calcite and diopside in approximately equal proportions. The garnet and calcite occur as anhedra up to 10 mm. across, arranged in alternate brown and green bands parallel to the bedding. Fine grained diopside and somewhat coarser wollastonite are poikilitically included in both garnet and calcite, though the wollastonite is largely confined to calcite.

IGNEOUS ROCKS

Introduction

Intrusive igneous rocks of the Sierra batholith directly underlie over 80 per cent of the area, and are presumed to be continuous underneath the metamorphic rocks. They all belong to the same intrusive sequence, generally considered to be of Late Jurassic age. No additional confirmation of this age was obtained from the area itself. The main body of the intrusive is a medium grained tonalite, having an abundance of small dark inclusions, of the type considered as autoliths by Pabst. Within the tonalite are minor bodies of diorite, one occurrence of gabbro, and many aplite and pegmatite dikes. Two large pegmatites intrude the metamorphic pendant.

Pabst, A. Observations on the Granitic Rocks of the Sierra Nevada.
Univ.of Cal.Pub.in Geo.Sci. v.17 p.325 1928

Diorite and Gabbro

Four bodies of diorite and one of gabbro were discovered in the eastern third of the area, and it is probable that others exist in their vicinity. All are less than 300 feet across in the known dimension (the direction of traverse) and all are surrounded by tonalite. Due to lack of outcrops it was not possible to determine the shape of these bodies in the time available. They are associated with an increased abundance of aplite dikes, which cut both diorite and tonalite.

The gabbro is a fine grained homogeneous rock of very dark color and micaceous appearance. It consists of 45 per cent labradorite, 30 per cent green hornblende, and 23 per cent biotite. The rock is fairly equigranular, grains averaging 0.3 mm., and shows typical gabbroic texture. Magnetite, in small grains, forms up to 2 per cent of the rock. The labradorite shows little zoning.

The other four bodies are made up of fine grained gray gabbro-diorite, which has white equidimensional feldspar crystals about 1 mm. in length in a groundmass of somewhat finer grained hornblende and biotite. This rock is composed of 38 per cent sodic andesine, 20 per cent labradorite, 22 per cent green hornblende, 18 per cent biotite and 2 per cent magnetite. Traces of epidote appear as alteration patches on labradorite.

The labradorite exists as skeletal remnants in process of replacement by andesine, which is the latest mineral in the sequence. Relics of labradorite, distinctive in plane light because of their high relief, are optically continuous, and clearly show the outlines of former euhedral crystals. (see Plate I). Replacement has not been confined to the rims of the labradorite, but has gone on erratically throughout the crystals. It is suggested that the diorite is a relatively basic facies, early in the intrusive sequence, which has been partially reworked by the more sodic tonalite magma, with which labradorite could not remain in stable equilibrium.

Tonalite

Tonalite is by far the most widely distributed rock type in the area. It is light colored, of typical medium grained granitic texture, and consists of about 80 per cent quartz and feldspar, biotite and hornblende making up the remainder. The hornblende is particularly well crystallized, euhedral prisms occurring up to 15 mm. in length. The rock is partially kaolinized and iron-stained to a depth of several feet, except in road cuts and stream beds. Exfoliation and spheroidal weathering are common features.

Though there is areal variation in texture, the composition of the tonalite is quite consistent, deviating very little from an average of 43 per cent andesine, 36 per cent quartz, 13 per cent biotite, and 5 per cent green hornblende. Alkali feldspars are erratic, varying from nothing to 10 per cent of the rock, and averaging perhaps 3 per cent. Accessory minerals are very minor. They include magnetite, apatite, sphene, and zircon. Epidote is found as an alteration product of plagioclase.

The alkali feldspar, where present, is partly microcline and partly an untwinned variety of albite, which replaces microcline. Both are very late and anhedral and enclose fragments of other minerals. There is considerable development of myrmekite, up to 1 per cent of the entire rock, usually on boundaries between plagioclase and alkali feldspar. Invariably the myrmekite either replaces microcline or else extends into albite which is itself a replacement of microcline, and never attacks the andesine crystal from which its own growth has been initiated. It may be considered as a special form of albitization, and therefore related to the accompanying late albite. Anderson, in describing almost identical relationships occurring in the White Mountains batholith, says -

> "Albite has replaced potash feldspar .... Often the substitution has taken place so delicately and yet so completely that the altered grain contains all of the characteristics of the original except in optic sign and index. It looks fresh and unchanged."

Anderson, G.H. Geology of the north half of the White Mountains Quadrangle. vol.2, p.26 Unpublished Ph.D. thesis, Calif Inst Tech 1933

In the tonalite of the Sugar Pine area even the grid pattern of microcline twinning may be accurately preserved in the albite pseudomorph. Anderson considers both the myrmekite and secondary albite to be of hydrothermal origin, because in the White Mountains the albitization is associated with veinlets and locally can be shown to have taken place following actual mechanical deformation of the rock.

Anderson, G.H. op.cit. p.40

Sederholm favors a deuteric or late magmatic origin for the majority of myrmekites, and this seems the most

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Sederholm, J.J. On Synantectic Minerals
Bull. Comm.Geol. Finland No.48 1916

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plausible explanation for the phenomenon in the Sugar Pine area. No relation was observed between degree of albitization and distance from the boundary of the intrusive.

Certain portions of the tonalite in the western part of the area, notably in Section 12, show a tendency towards foliation of the dark minerals. This texture is probably a result of shearing stresses in the rock after consolidation, since the quartz and feldspar appear shattered, and these zones are always more thoroughly weathered than the normal tonalite, suggesting internal weakening of the rock.

Autoliths

The tonalite contains a multitude of dark crystalline inclusions, of a type common throughout the batholith. They are subangular or rounded, and though most are only a few centimeters in length, they may reach 20 or 30 cms. Parallelism of these inclusions is infrequent.

The composition averages 55 per cent andesine and

23 per cent hornblende, with 10 per cent biotite, 7 per cent quartz, and 5 per cent microcline. Traces of myrmekite and secondary albite occur. One autolith studied had over 1 per cent sphene in megascopic crystals. Similar sphene was seen in the adjacent tonalite. The inclusions are fine grained, about 0.2 mm., and of dioritic texture, except for the presence of large sieve crystals of microcline. The quartz is distributed in very small interstitial anhedra. The boundaries of the inclusions are sharp, though made up of mutually interlocking crystals, and are not characterized by textural modifications either in inclusion or host.

Pabst, in discussing the theory that these autoliths are stoped fragments of an early intrusive border facies, says –

> "The writer has not seen in the Sierra Nevada any rocks of the type of the autoliths described in any other form than as inclusions in granitic rocks."

Pabst, A. op.cit. p.367

While the petrographic evidence presented here is insufficient basis for generalized conclusions, it is suggested that small stoped fragments of such a rock as the gabbro of this area may have been reworked into "autoliths" by reaction with the tonalite magma. In grain size, texture, and dominance of hornblende over biotite the gabbro resembles the autoliths studied. The small diorite bodies are believed to form a connecting mineralogical link in the progressive establishment of equilibrium between inclusions of basic rock and their tonalite host. The diorite shows extensive replacement of labradorite by andesine, but has no quartz, no alkali feldspar, and no myrmekite, all three of which may be found in the autoliths, though in much smaller quantities than in the surrounding tonalite.

Pegmatite and aplite

Within the intrusive are a large number of small leucocratic dikes, from 5 cm. to 1 m. in thickness, and occasionally larger. These dikes are particularly abundant on the lower west slopes of Wells Mountain. No consistency of trend is apparent, but a majority of the dikes have low dips, from 10° to 30°. The dikes exposed along the highway in Section 13 are notable exceptions; they have steep dips. On the basis of texture the dikes may be divided into three groups, aplite, pegmatite, and banded pegmatite. All have straight clean walls and show little change in width.

The aplites are even-textured, with an average grain size of 0.8 mm. They are made up of quartz and feldspar, with a little biotite and locally a few small red garnets. The rock is white, hard, and resistant to weathering. Its average composition is 30 per cent calcic oligoclase, 35 per cent quartz, and 35 per cent untwinned albite, with less than 1 per cent of biotite and muscovite. The albite in many places preserves almost perfectly the grid twinning pattern of microcline, and it is presumed to represent the completion of the incipient albitization of potash feldspar seen in the tonalite.

The pegmatite group is characterized by heterogeneity of grain size. Aplitic texture prevails in many places, but it is intermixed with irregular bands and masses of large feldspar and quartz crystals.

The most interesting dikes are the banded pegmatites, having a symmetrical distribution of textures parallel to their walls. The common arrangement consists of an outer zone of coarsely crystalline feldspar and quartz, separated by a thin band of aplite from a central core of biotite granite.

None of these small dikes have been found in the metamorphic rocks. They cut both diorite and tonalite, indicating that they represent the last stage of intrusion.

Two large dikes, the Speckerman pegmatite near the summit of Wells Mountain, and the Tin Bucket pegmatite on its southeast slopes, cut into the metamorphic rocks of the main pendant. Both are nearly straight in trend, the former having a strike of N 86°W and a dip of about 70°N, and the latter striking N 30°E and dipping about 80°W. Both have an average thickness of 50 feet. Neither dike is connected with the main body of the batholith at the surface, but from their similarity to the pegmatites in the tonalite it is presumed that they are derived from the intrusive at depth. The south end of the Tin Bucket pegmatite is in contact with a small outcrop of tonalite or granodiorite. This contact is best seen in the tunnel shown just west of the half section line in Section 7. (see Plate III)

The mineralogy of both pegmatites is similar; they are made up of quartz and a feldspar of undetermined composition, with minor amounts of biotite, Weathering of the biotite and release of iron oxides gives outcrops a patchy pink color. The texture of the two dikes is different, the Tin Bucket pegmatite being truly pegmatitic and very coarse in grain, with only occasional aplitic portions in its narrow parts. The Speckerman pegmatite on the other hand shows all gradations of grain size, with the coarsest material in veinlets and irregular masses. In this respect it closely resembles the small pegmatites in the intrusive on the west side of Wells Mountain, with which it is genetically related.

UNCLASSIFIED CONTACT ROCKS

In the northern half of the pendant the major part of the contact between the metamorphic rocks and the intrusive is marked by a gradational zone of so-called "mixed rocks". This zone is locally several hundred feet in width. It is best exposed along the road near Alder Creek in Section 5, where all the facies typical of other outcrops of the zone may be seen in a single sequence.

On the west side of Alder Creek, along this road, quartz sericite schist and biotite schist are in contact with a rudely foliated medium grained biotite gneiss. With foliation decreasing evenly over a distance of 400 feet to the creek, this gneiss grades into a tonalite or granodiorite of normal igneous texture. The intermediate gneiss, mineralogically a granodiorite, is of crushed and strained appearance, foliated by rough alignment of biotite. Measurements of the attitude of foliation differed widely, and were insufficient to establish a consistent trend. The rock near the middle of the gneissic zone is 46 per cent andesine, 25 per cent quartz, 13 per cent microcline and untwinned albite, 10 per cent biotite, and 6 per cent hornblende. Most of the plagioclase is in large,poorly twinned grains, badly cracked. The fracture pattern, which is highly irregular, reveals no displacement. Other minerals, including the rest of the plagioclase, which is finer grained and well twinned, appear fresh and unstrained.

On the east side of Alder Creek, still on the same road, but now in a direction returning towards the pendant, this same gneiss grades into a fine grained rock composed almost entirely of equigranular quartz, potash feldspar, and well-lineated biotite.

Continuing south on the road for 1500 feet, roughly paralleling the main contact, sections of normal schist and quartzite alternate with a fine grained dark gray "mixed rock", poorly foliated and thoroughly shattered, showing small white weathered feldspars in a biotitic groundmass. This rock contains subequal proportions of plagioclase, quartz, hornblende, and biotite, with an average grain size of 0.2 mm. Plagioclase is again badly cracked, and thoroughly altered to zoisite and kaolin. Other minerals show no sign of strain. Hornblende is anhedral and ragged, full of minute inclusions of quartz and possibly feldspar, indicating a metamorphic origin.

In the absence of detailed information on the field relations of these "mixed rocks", the relative importance of sedimentary and igneous processes in their formation cannot be evaluated. Wide contact zones of reconstitution and apparent assimilation such as this are not common in the Sierra Nevada.

Mayo, E.B. Intrusives and Wall Rocks in the Sierra Nevada
Jour.Geol XLIII p.673 Oct'35

STRUCTURE

Regional structure

A discussion of the large scale structure of the area resolves itself into a distinction between inclusions and roof pendants in the batholith. This distinction depends partly on size and partly on the degree of conformability with the regional strike. The regional strike in the western Sierra Nevada is about N 30°W, while the average strike of the metamorphic rocks in Sections 6 and 7 is N 10°E. Nevertheless it is credible that this deviation was caused by local warping, and in view of its size this central area is believed to be a roof pendant.

The small areas of metamorphics in Section 8 might well be inclusions, though no reliable indications of attitude were seen therein. The two remaining bodies of metamorphic rocks, one in the northwest corner of Section 6 and the other in the southeast corner of Section 17, extend beyond the area mapped and are therefore of unknown size. Their attitudes are disconformable both to the regional strike and to the strike of the main pendant. It is possible that the southern body is a continuation of the metamorphic rocks known to outcrop around Bass Lake, several miles to the southeast.

No attempt was made to map flow structures in the intrusive.

Folding

The metamorphic rocks have been tightly folded by east-west compressional forces. The steep dips, often reversed, and the abundance of tight minor folds and crenulations indicate strong folding, even though no individual structures could be mapped.

To a verymuch lesser extent there is also evidence of north-south compression, notably on top of Wells Mountain and in the calcareous rocks of Section 17. In these localities the beds are contorted in sigmoidal bends, several feet in length, along the strike.

Faulting

No fault with recognizable offset was found in the area, but there are indications of a fracture zone cutting both the intrusive and the metamorphic rocks on the west slope of Wells Mountain, striking N 36°E. The comparative straightness of the zone across variable topography indicates steep dip. The trace of the fracture is outlined by four springs, the southernmost of which is at Corlieu Springs, near the main highway in Section 13. Here warm, slightly sulphurous water, with gas bubbles, issues from a sheared zone in tonalite. The fracture at this point strikes N 25°E and dips 85°W. The upper three springs, which give fresh cold water, occur at such an elevation on the west slope of Wells Mountain that it is difficult to see how the slope immediately above them could supply them with water well into the late summer, and even through the winter. The only extensive watershed available to these springs is on the high ridge to the northeast, which would be bisected by an extrapolation of the line of springs. It seems, therefore, that the fracture zone serves as a structure for the concentration and transmission of water. The possibility of a water-bearing stratum as a source for the springs is ruled out by the disconformity between the line of springs and the prevailing strike, and by the absence of porous rocks in the pendant.

Nearly half a mile east of the fracture zone, on the east side of Wells Mountain, is another perennial spring of considerable volume. It supplies water to Mirimichi Ranch in Section 18. Water seeps out over several hundred square feet of a relatively flat area on the mountainside, and runs into West Alder Creek, where it passes through settling tanks and an underground pipeline to the ranch. The structural control for this spring is not apparent at the surface. The spring is near the east end of the Speckerman pegmatite, and it is probable that underground extensions of this dike divert part of the water coming through the fracture zone in the saddle north of Wells Mountain.

The fracture zone has no topographic expression, and no recognizable cataclastic materials were found along its trace, though in many places where it cuts the tonalite there is unusual development of exfoliation. Since the fracture cuts the intrusive it is post-Jurassic in age.

Evidence of shearing stresses in the intrusive at other points is found in the roughly gneissic foliation described on Page 19.

GEOLOGIC HISTORY

The earliest geologic event recorded in the area is the deposition of large thicknesses of sandstone, with subsidiary argillaceous and calcareous beds in Late Paleozoic time. The presence of limestone, the absence of conglomerate, and the regularity of bedding suggest a marine origin for these beds. Early Mesozoic history is unknown, but at some time before the Late Jurassic the sediments were strongly folded by east-west compressional forces. This folding was part of a widespread diastrophism which affected the whole Sierran region. The folding of the rocks now exposed in this area took place at depth, since the shape and texture of the batholith later emplaced around the sediments indicates crystallization several thousand feet below the surface. The higher temperature prevailing at depth, together with compression, brought about compaction and regional metamorphism.

In Late Jurassic time the several facies of the Sierra batholith were intruded, in order of increasing acidity. Early basic facies were partially reworked by the tonalite magma while the latter was still fluid. The pegmatites and aplites were emplaced towards the end of the intrusive sequence. Ore deposition was also a feature of the last stages of intrusion, as shown by its association with pegmatite. Contact metamorphism of the margins of the intruded rocks is presumed to have continued throughout the sequence.

The post-Jurassic history of the area has been one of intermittent uplift and erosion, bringing the batholith to the surface and leaving only roots of the folded rocks. The fracture zone is believed to be a relatively young feature, because of its lack of mineralization. It may have accompanied the Pliocene tilting of the Sierra Nevada fault block.

Pleistocene glaciation, spreading over the Yosemite region, stopped three miles north of the Sugar Pine area.

State Geological Map of California 1937
(Glacial map by F.E.Matthes)

At the present time the area is in an erosional stage of early middle maturity. Streams are ungraded, slopes are quite steep, and relief is close to its maximum value. The influence of structure on topography is becoming apparent on Wells Mountain, where the resistant metamorphic rocks develop steeper slopes than the surrounding intrusives.

ORE DEPOSITS

Introduction

Tungsten, manganese and molybdenum are found in the Sugar Pine area, though only tungsten is worthy of economic consideration. Tungsten occurs in scheelite, disseminated in the tactite adjacent to the Tin Bucket pegmatite in Section 7. The molybdenum is found in the pegmatite itself, in which it is syngenetic.

Tungsten

Scheelite is practically confined to two deposits, located respectively at the north and south ends of the Tin Bucket pegmatite, on the southeast slope of Wells Mountain, in Section 7. (see Plate III) The mineral occurs as fine to medium grains disseminated in a garnet-quartz-diopside tactite formed by contact metamorphism of calcareous beds (see Page 13). Outcrops of the tactite are poor, and information was gained mainly from prospect pits.

The north portion of the Tin Bucket pegmatite strikes N 30°E and dips about 80°W. Its average width is less than 50 feet, broadening to the north. 50 feet east of the north end of this pegmatite are two prospect pits, each about ten feet square. The northern pit is in schist, and contains no scheelite. The other pit exposes on its east side a 7 foot thickness of tactite, which carries about

1 per cent of very fine grained scheelite, with traces of chalcopyrite. The scheelite is well disseminated through the tactite, and where irregularities in concentration occur these show no structural control within the pit. 160 feet S 5°W is a slightly smaller pit in the same type and grade of ore, except that both tactite and scheelite are of coarser grain, up to 3 mm., and distribution of the scheelite is more patchy.

The two pits in the tactite are on line with the regional strike, and represent the same limy zone. Schist and granulite outcrop between the pits, however, indicating two lenticular tactite bodies, parallel to the bedding of the schist, each probably 50 feet in length, and with a maximum width of ten feet. The tactite showing outside the pits has less scheelite, and the average grade of the lenses is estimated at 0.5 per cent scheelite. The dip of the tactite was not observed directly, but its conformability with the sediments indicates a dip of 75°W.

In thin sections of the tactite the distribution of scheelite is not controlled by fractures or other minor structures. It is disseminated as equidimensional subhedra up to 3 mm. in width, distinguished by their high relief and dirty, colorless appearance. They are surrounded, but never cut, by diopside, garnet, and quartz. Some of them contain small inclusions of anhedral diopside, and rarely of calcite. The scheelite is of pyrometasomatic origin, derived from the pegmatite. It is later than diopside, but its age relations with garnet and quartz are not clear.

40 feet west of the half-section line of Section 7, near the south end of the Tin Bucket pegmatite, is an exploratory adit 60 feet in length. This adit runs N 10°W and lies entirely within the National Forest. It begins in a small pegmatite stemming directly from tonalite or granodiorite, and the rear half of the adit follows a contact between this pegmatite and quartzite, the end face being in quartzite. Small patches of tactite, amounting to perhaps 50 square feet in all, and running 1.5 per cent scheelite, appear on the east wall of the adit in the metamorphic rock. More tactite of the same grade was in the dump below the adit.

On the slope 100 feet northwest of the adit entrance are three prospect pits exposing small tactite lenses in bedded quartzite. Individual lenses, which conform to the bedding, average 4 feet in length and less than a foot in maximum thickness. The tactite lenses contain 1 to 1.5 per cent scheelite, here fairly coarse grained. The average value of the rock showing in the pits, including the barren quartzite, does not exceed 0.5 per cent. The structural relations between the tactite in these pits and that in the adit are obscured by slide and dump material. There has been local folding, shown by frequent dip reversals in the quartzite. Although this folding antedates the mineralization, it involves the calcareous lenses which control the ore. Any attempted exploitation of this deposit should be preceded by trenching east and west, across the strike of the beds, to correlate these folded structures.

There is no reason to expect less lensing of the tactite bodies in depth, indeed individual lenses may pinch out entirely, and therefore the extent of the ore probably does not increase below ground. About 1000 tons of ore are in sight, with a total content of less than 500 units, or 5 tons, of WO_3. Several times this quantity of waste rock would have to be mined out to extract the ore. At the present price of domestic tungsten, 26 dollars per unit, development of this property is not advisable, in view of the very short life expectancy of the necessary installations. Deposits recently brought into production in other parts of the Sierra Nevada, notably near Bishop, are of a very much greater order of magnitude.

The only other observed occurrence of scheelite is in the banded garnet rock in the small area of metamorphic rocks in Section 17. A few medium sized grains of the mineral were seen in specimens from this locality, but no indications of ore. The locality was not prospected with the ultra-violet lamp.

Manganese

Manganese oxides, mainly pyrolusite, in a gangue of vein quartz and a pink bladed pyroxene, are found at the summit of Wells Mountain north of the Speckerman pegmatite. The pyroxene, which is a mid-member of the diopside-hedenbergite series, probably owes its color to small amounts of manganese. The deposit is a small hydrothermal vein, trending N 60°E across the strike of the quartzite, and having ragged indefinite walls. Its outcrop is not traceable for more than 50 feet east and west of the prospect pit, where it is best exposed. Infiltration of manganese oxides along cracks creates the appearance of rich ore, although the material is largely gangue. From the standpoint of both size and grade the deposit does not justify development.

Molybdenum

Molybdenum, occurring in the form of molybdenite, is of mineralogical interest only. It is found in a prospect pit and small adit, presumably excavated in a search for gold, at the north end of the south segment of the Tin Bucket pegmatite. Molybdenite in small platy masses is very sparsely distributed through the pegmatite. In view of the absence of other signs of mineralization, the molybdenite is believed to have crystallized directly from the pegmatite.

Economic Possibilities

Within the area investigated, scheelite is the only mineral of potential economic interest. The quantity of scheelite is insufficient to justify exploitation. Consequently the area studied appears to have no mineralization worthy of future consideration.

Diorite - showing replacement of labradorite by andesine.

Specimen 21 SW Section 17

In the large central grain, and also in the grain in the upper right-hand corner, the dark areas are labradorite and the light areas andesine. The dark minerals on the right are hornblende and biotite.

Crossed nicols Magnification 30

PLATE I