GEOLOGY OF AN AREA NEAR
INGOT, CALIFORNIA

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By

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ABSTRACT

The area covered by this report lies about five miles northeast of Ingot, and 24 miles northeast of Redding, Shasta County, California, along the U. S. Highway 299. It is about four square miles in area. The geology of this region has not been mapped in detail. It contains sedimentary and volcanic rock of Mesozoic and Cenozoic ages.

The Pit Formation of Middle to Late Triassic age, consisting of yellowish-grey shales, black carbonaceous shales, feldspathic graywacke sandstone, compact hard siltstones, and impure limestone, form the oldest rocks. They are isoclinally folded. The period of deformation is believed to be Late Jurassic or Early Cretaceous.

All these sediments are characterized by compositions low in quartz, high in plagioclase (oligoclase) and lithic grains, and with a high matrix content. The angular grains and the high matrix content indicate short distance of transport and rapid sedimentation. The high content of volcanic lithic fragments and low quartz content indicate derivation from a volcanic source area having few quartz-bearing rocks. Except for one basaltic andesite sill, the lack of lavas suggests lack of volcanic activity within the mapped area. Fossils from the youngest shale indicate Late Triassic age.

The dominant strike is northwest to north-northwest and the dip varies from 30° to 80° towards the southwest.

Unconformably above the Pit Formation is the Tuscan Formation of friable tuffs, conglomerates with rounded pebbles, and loosely cemented arkosic sandstone. These beds are mainly fluvial and mudflow deposits,

and are believed to be of Pliocene age. They dip gently to the southwest.

Overlying an erosional unconformity on the Tuscan are basalts. Three types are recognized; they are mainly olivine basalt flows. These basalts are believed to be of Pliocene to Pleistocene age.

The main stream valley is covered with Quaternary alluvium. The basaltic area is a plateau being dissected by youthful streams.

Small quarries for crushed rock for local roads are the only aspects of economic geology in the area.

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INTRODUCTION

GENERAL STATEMENT

The area mapped is rectangular in shape and approximately four square miles in size, located in the extreme southeastern corner of the Bolliboka Mountains Quadrangle, Shasta County, California (U. S. Geological Survey, 15 minute series map number N 4045-W-12200/15). The southeastern corner of the region is approximately marked by 40°45' N latitude and 122°00' W longitude. The area lies 24 miles northeast of Redding along U. S. Highway 299 (Fig. 1). The highway traverses the region from southwest to northeast, up the valley of Cedar Creek.

The climate during the period of work was hot and dry, the highest temperature reaching 109°F. Light rain was encountered now and then.

Most of the area is covered by thick, dense forests and brush, whereas the hilltops in general were bushy. Pine and oak trees are very common.

ACKNOWLEDGMENTS

I am very grateful to Mr. and Mrs. Louis Colbert for their hospitality in allowing me to stay with them during the entire field work period. My thanks are also due to the geologists at the California Division of Mines, Redding, for giving me access to recent literature on the area.

PREVIOUS WORK

The area under consideration has not been mapped in any great detail. However, a brief survey of previous work carried on in

FIGURE 1· INDEX MAP SHOWING LOCATION OF THE AREA OF THIS REPORT adjacent regions by early workers should be of interest.

The first geologic account of sedimentary rocks in Shasta County was by J. B. Trask (Whitney, 1865). No further geological work followed Trask's reconnaisance until the early 1890's, but from 1893 to 1906 several geologic reports were published. J. S. Diller, of the U. S. Geological Survey, published (1893) a broad scale geological map of Northern California. In a paper on the geology of the Lassen Peak district, Diller (1889) first mentioned the presence of Mesozoic sediments older than Cretaceous in the vicinity of Pit River and Montgomery Creek. Pit River flows about 2.25 miles north of the present map area.

Fairbanks (1893) wrote a general account of the geology and minralogy of Shasta County, and later published some supplementary notes on his geologic work in Shasta County and briefly described the various lithologic units of the region as then understood (Fairbanks, 1894).

Diller (1906) revised the stratigraphy of this area in the Redding Folio, which contains an excellent geologic description of the stratigraphic units of Shasta County, and which has served as a basis for practically all geological work done in the Redding area since 1906. This Folio's geologic map, at a scale of 1:250,000, covered the area now under investigation.

L. C. Graton (1910) reported on the copper deposits of Shasta County. Reports by N. E. A. Hinds on the Paleozoic eruptive rocks of the southern Klamath Mountains (Hinds, 1932), on the geological formations of the Redding and Weaverville Quadrangles (Hinds, 1933), on Mesozoic eruptive rocks of the Klamath Mountains (Hinds, 1935), and on the Paleozoic section in the Klamath Mountains (Hinds, 1940) comprise the more recent literature on the geology of the adjacent area. J. P. Albers (1953) described the geology of the Afterthought Mine. "Geology and ore deposits of East Shasta Copper-Zinc district, Shasta County, California", by Albers and J. F. Robertson (1961) is the most recent and detailed account under consideration.

The adjoining area to the west and northwest is underlaid by sedimentary, volcanic, and intrusive rocks ranging in age from probably Middle Devonian to Late Jurasic or possibly Early Cretaceous. In general, except for intrusive units, the oldest formations in the basement-rock sequence crop out in the western part of the area and successively younger units crop out towards the east (Albers and Robertson, 1961).

The rocks are predominately marine clastic sediments derived from the erosion of volcanic flows and associated pyroclastic material together with subordinate limestone deposits and considerable amounts of pyroclastic rocks and lava.

Poorly consolidated fluvial sandstone and conglomerate of Pliocene age unconformably overlie the Mesozoic strata. These beds in turn are unconformably capped by andesitic and basaltic flows and pyroclastic accumulations associated with the Pliocene Cascade lavas.

About 50 to 60 percent of the layered basement rocks are of volcanic origin, irregularly distributed through the stratigraphic column (Albers and Robertson, 1961). Most are hydrothermally metamorphosed and they now range in composition from mafic spilite to silicic quartz keratophyre.

The Mesozoic deposits in the adjacent areas are composed of pyroclastic rocks, lava flows, tuffaceous sandstone, argillite, and limestone. The Mesozoic formations, from the oldest to the youngest, are the Pit Formation of Middle and Late Triassic age; the Hosselkus Limestone, Brock Shale, and Modin Formation of Late Triassic age, the Arvison Formation of Early Jurassic age; and the Bagley Andesite and Potem Formation of Early and Middle Jurassic Age. During Late Jurassic and possibly Early Cretaceous time, these layered rocks were folded and faulted, and intruded by a small grandodioritic stock and by dikes and sills of fine grained igneous rocks, chiefly of mafic character (Albers and Robertson, 1961).

Profound orogeny, including folding, albitisation and chloritization, as well as mineralization, occurred probably during the Late Jurassic or possibly Early Cretaceous time (Albers and Robertson, 1961).

Extensive widespread erosion followed the orogeny. The Tuscan Formation was deposited on this surface during Pliocene time. Minor uplift and erosion of the Tuscan was followed by the extrusion of basaltic lavas in the eastern part of the area during late Pliocene or possibly early Pleistocene time (Albers and Robertson, 1961).

PRESENT WORK

The field work consisted of geologic mapping and the collection of specimens for laboratory study. A period of 35 days was spent in the field during June and July, 1967. The geological data were plotted on a 1:13,000-scale base map enlarged from the original 1:62,500 scale U. S. G. S. topographic map. The pattern of mapping adopted was by traversing along all possible roads, footpaths, and valleys.

Geologic sections were measured and estimated by pace and compass methods. Observation points in the field were transferred to the topographic sheets by the help of sights, with the Brunton compass, on important landmarks or cultural features. Each point of observation was referred to as a locality and was marked on the topographic sheet to keep an accurate record of the location of the observation points (Fig. 2).

Field data such as dip and strike of bedding, plunge and bearing of minor fold axes, and dip and strike of schistosity were recorded.

During the course of the field investigation, about 250 specimens of various rock types were collected. Some of them were oriented samples. About 150 representative specimens were brought back to Hawaii. The collection of samples in a more or less grid pattern was not possible due to several factors, mainly lack of suitable exposures on hill slopes and presence of dense forests and brush. Thus most of the sampling was in conjunction with the mapping traverses along stream valleys and road cuts.

LABORATORY PROCEDURE

About 80 thin sections were studied under the petrographic microscope to determine the mineral constituents and texture of representative rocks. Modal analyses of the composition of some of the sandstones, argillites, and limestones were made by the pointcount method. Traverses of the thin sections along straight lines were stopped at regular intervals by a click-stop attachment to the mechanical stage of the microscope. The 300 points counted for each slide were converted to percentage composition, and the analyses plotted on diagrams.

Composition of plagioclase feldspar was determined by matching the refractive index, using the oil immersion method, to compositional

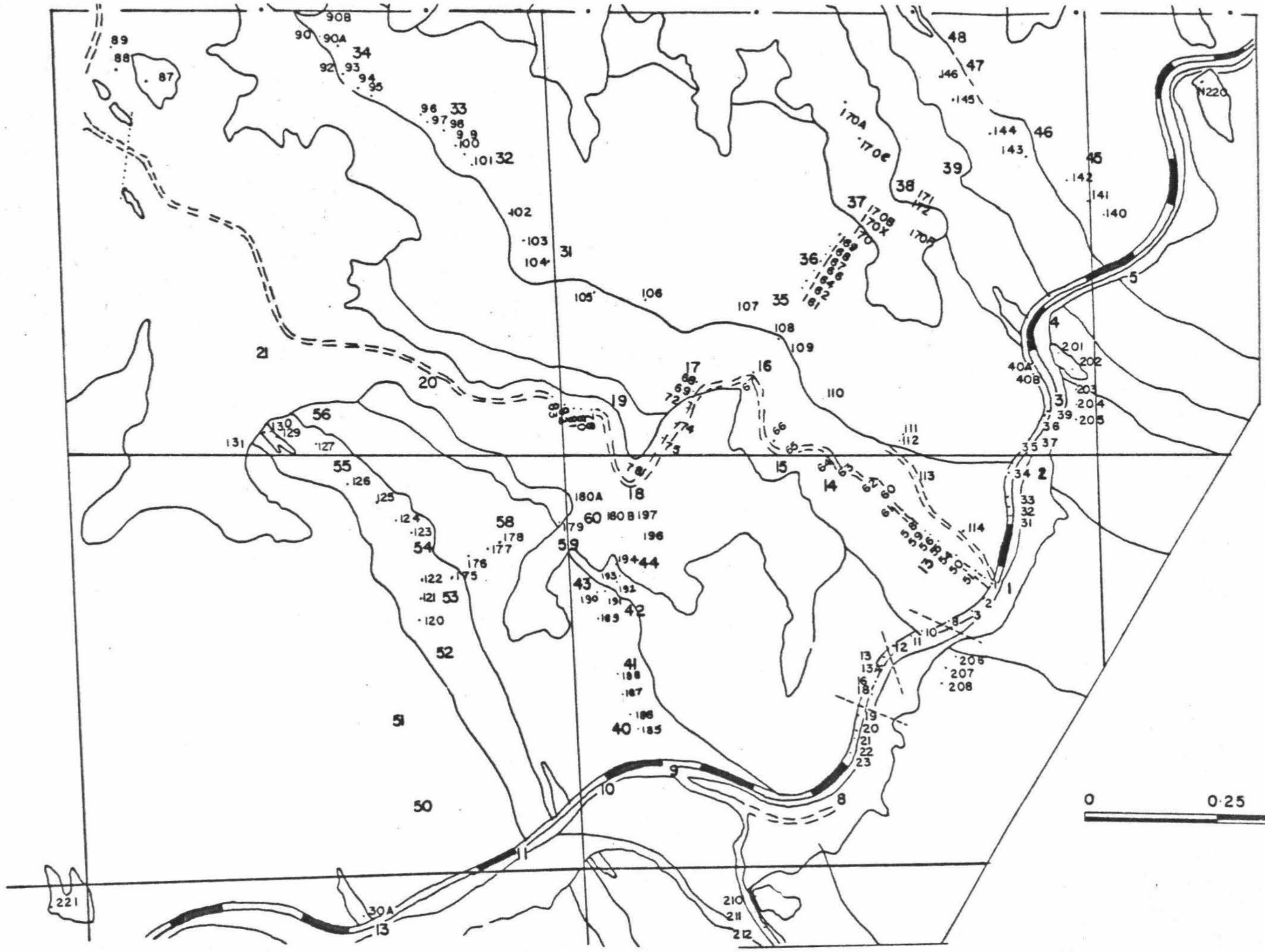


FIGURE 2. SAMPLE NUMBERS & LOCATION MAP.

(CONTACTS AS ON GEOLOGIC MAP.)

23 LOCATION NUMBERS.

108 SAMPLE NUMBERS.

0 0.25 0.5 0.75 1

SCALE IN MILES.

curves (Bloss, 1961). The compositions of microlite feldspar grains were determined by the method of maximum extinction angle (Heinrich, 1965, p. 362-364). In the measurements of optical axial angles (2V), the methods of Tobi (Bloss, 1961, p. 205), Kamb (Bloss, 1961, p. 179-180), and Wright (Bloss, 1961, p. 203) were used.

GENERAL GEOLOGY

GEOMORPHOLOGY

The area lies in the Cascade Range geomorphic province. The region is drained by Cedar Creek and Little Cow Creek, and by tributary system along Bear and McCandless Gulch. The general elevation of the main valley floor is about 1200 feet whereas the highest elevation is above 2300 feet. Whereas the main streams are transverse to the regional structure, the tributaries are nearly parallel to it. Cedar Creek has cut a steep valley trending west-southwest. Between the time of deposition of the Tuscan Formation and the present, the main streams have become incised into the basement rocks 600 to 800 feet, as indicated by the fact that fluvial deposits belonging to the Tuscan Formation are now found capping the hilltops. The tributary streams, keeping pace with the rapid down cutting of the master streams, have cut deep steep-sided canyons, giving sharp topographic relief to the region. The tributary stream valleys are strike valleys in most cases. The generally concordant altitudes and gentle relief of the flat-topped uplands reflect a former continuous, gently sloping surface. All the above factors indicate that the area was uplifted in post-Pliocene time. The area appears to be in the youthful stage of fluvial erosion cycle.

STRATIGRAPHY

Pit Formation

The Pit Formation was named by Fairbanks (1894) for exposures along the Pit River at Silverthorne's ferry. The sedimentary rocks consist mainly of interbedded, medium-gray, laminated shales which are severely crushed, and black, carbonaceous, dense siltstone which is compact, well cemented and possesses abundant matrix (Diller, 1906, called it "argillite"). Others include black, dense, carbonaceous shales with good fracture cleavage; massive, medium to dark gray limestones; impure cleavable carbonaceous and massive impure limestones; and thin layers of feldspathic graywacke (Fig. 3). No volcanic flows are found interbedded with the sediments. Only in the northwestern part of the area fine-grained microporphyritic andesitic basalt is present as a lense-like body. Presumably it is a sill since it does not persist across the region and because the siltstone in contact with it is strongly indurated for several feet, as if it were baked.

The dominant strike of the formation is roughly northwest or north-northwest. The dips range from 30° to 80° toward the southwest.

The bedding in the sediments of the Pit Formation may be assigned to class B of Pettijohn and Potter (1964, p. 5). The beds are characterised by unequal thickness, they are laterally uniform, and are continuous. Some of the beds are laminated while others like the siltstone are hard and massive, possessing little internal structure.

Current bedding and graded bedding were almost lacking in the region. A single case of each was noticed in the same area near location 34. Whereas the current bedding indicated inversion of the beds, the graded bedding suggested that they are in normal position.

These oldest rocks of the area, because of their close resemblance in lithologic characters to those of the Pit Formation, and because they seem to form a continuous link with the above formation in the adjacent area, have been designated the Pit Formation. This is further

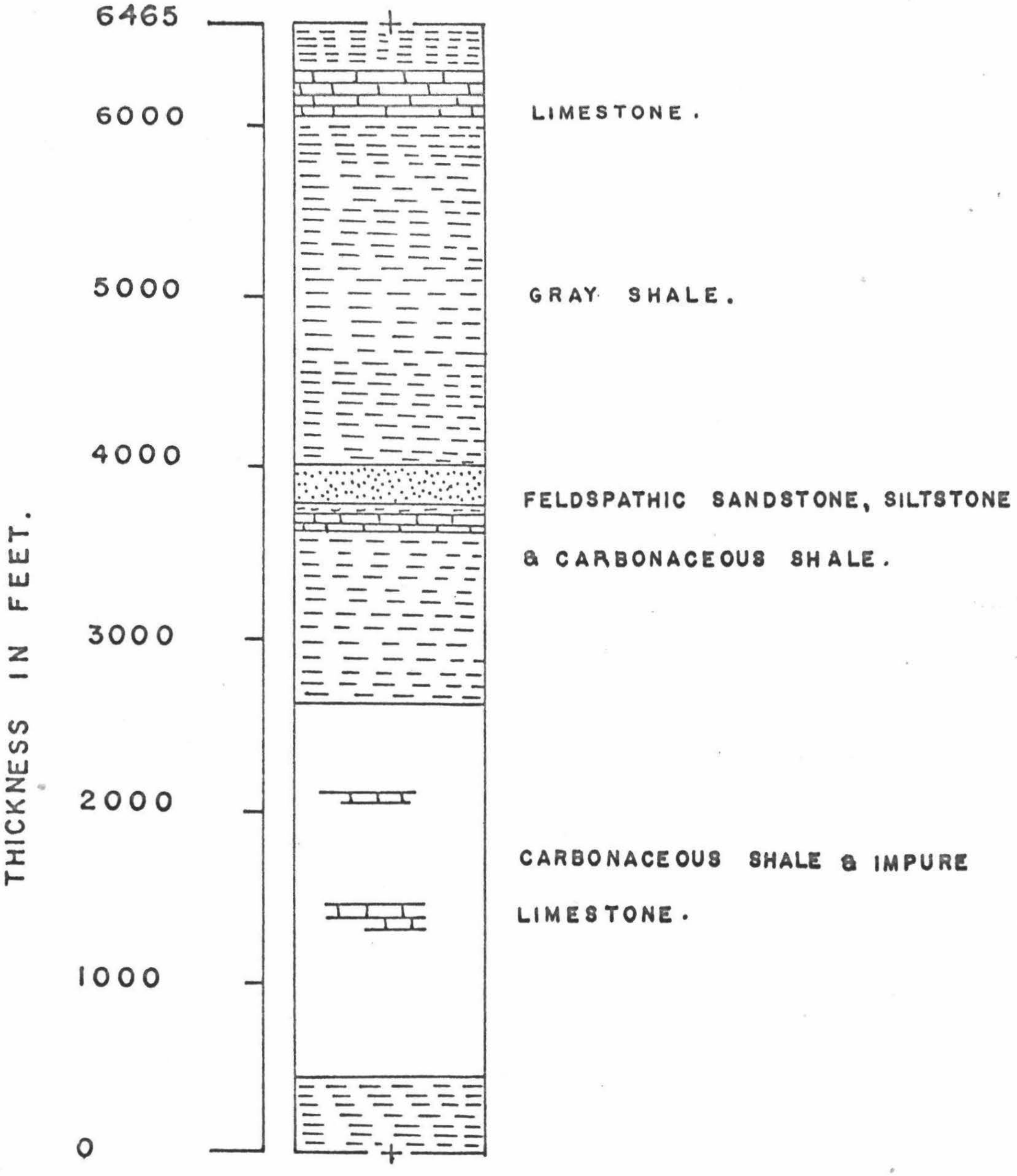


FIGURE 3. COLUMNAR SECTION OF THE PIT FORMATION.

substantiated by the presence of Upper Triassic fossils in some of the shale. However, the age of the Pit Formation is believed to be Middle to Upper Triassic. The structure section suggests the thickness of the Pit Formation to be more than 6,465 feet (Fig. 4); Albers and Robertson (1961) estimate 5,000 feet, while Diller (1906, p. 4) estimated it to be "somewhat over 2,000 feet". The Pit Formation is termed part of the "basement" by Albers and Robertson (1961).

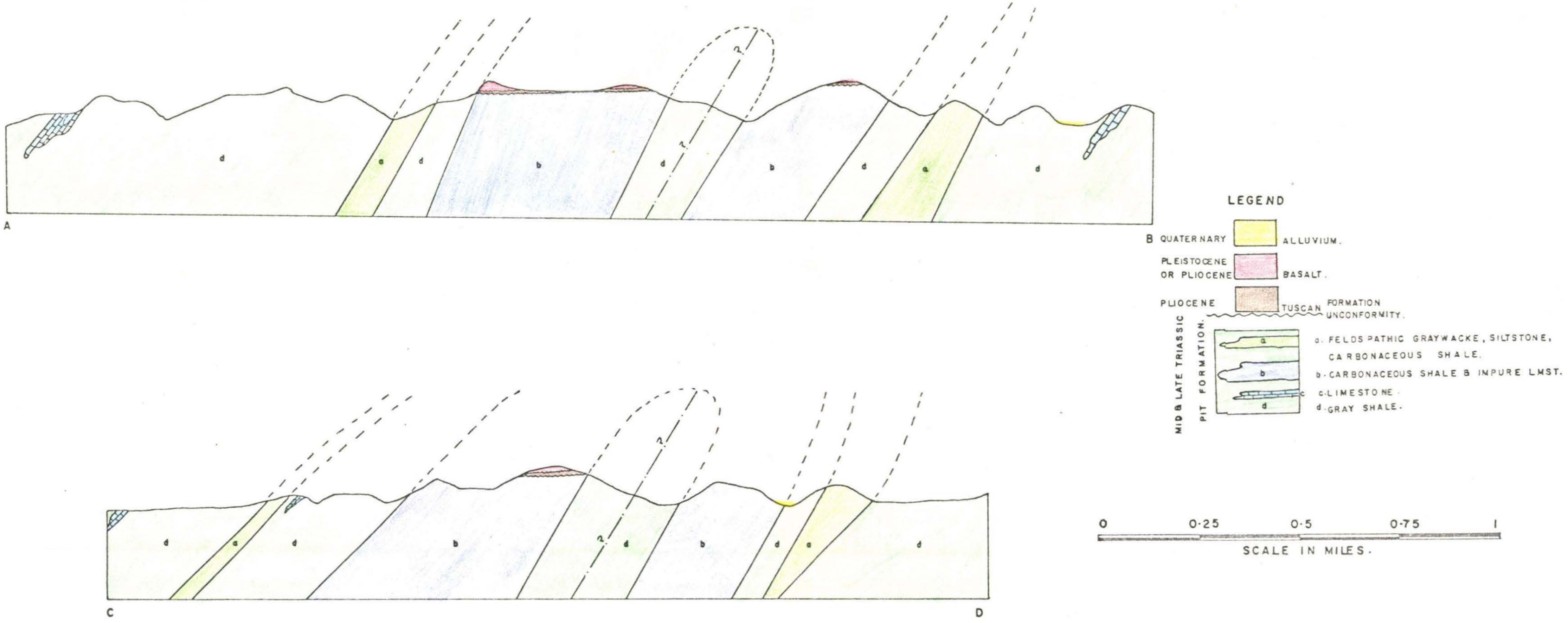
Tuscan Formation

A series of rocks consisting predominantly of tuff breccias with associated volcanic conglomerates, volcanic sands, coarse to fine tuffs and tuffaceous clays was named the Tuscan Formation by Diller (1895). The type area was Tuscan Springs. The Tuscan Formation of this area is soft, friable tuff breccia, conglomerate with well-rounded pebbles and boulders, and grayish-orange weakly consolidated medium- to fine-grained arkosic sandstone. The beds are nearly undeformed and occur unconformably above the deformed rocks of the Pit Formation. They have a gentle dip towards the southwest. The Tuscan is overlain by basalt flows. The Tuscan Formation is believed to be mainly a mudflow deposit of Pliocene age (Anderson, 1931, p. 8). The thickness ranges from a few feet to as much as 250 feet.

Tertiary Basalts

These occur in isolated patches on the hilltops and probably lie above the Tuscan with an erosional unconformity. Three types of basalt were recognized and they are all fresh. They generally dip at a low angle toward the southwest, but locally the dips change. The thickness

FIGURE 4· GEOLOGICAL SECTIONS ALONG A-B & C-D.



could not be definitely established. They are of very latest Pliocene or Pleistocene age, (Fig. 5).

STRUCTURE

Regional Structure

To the west and northwest of this area, Albers and Robinson (1961) mapped general structural trends that strike northwestward. Farther west, the trends strike more to the north or northeast. In the area of this present investigation the strike of bedding and of fold axes is generally northwest. It is a part of the Nevadan Orogenic Belt.

Fracture Cleavage

Secondary planer structures are shown locally by certain rock types. These range from a weak to a prominent fracture cleavage. They are prominent in the cleavable black carbonaceous shales, in some cleavable black carbonaceous shales, in some cleavable limestone and also locally in the greyish-yellow shales.

Where it is prominently developed, the cleavage almost parallels the bedding in strike, but its dips are usually higher, from 45 to 80 degrees.

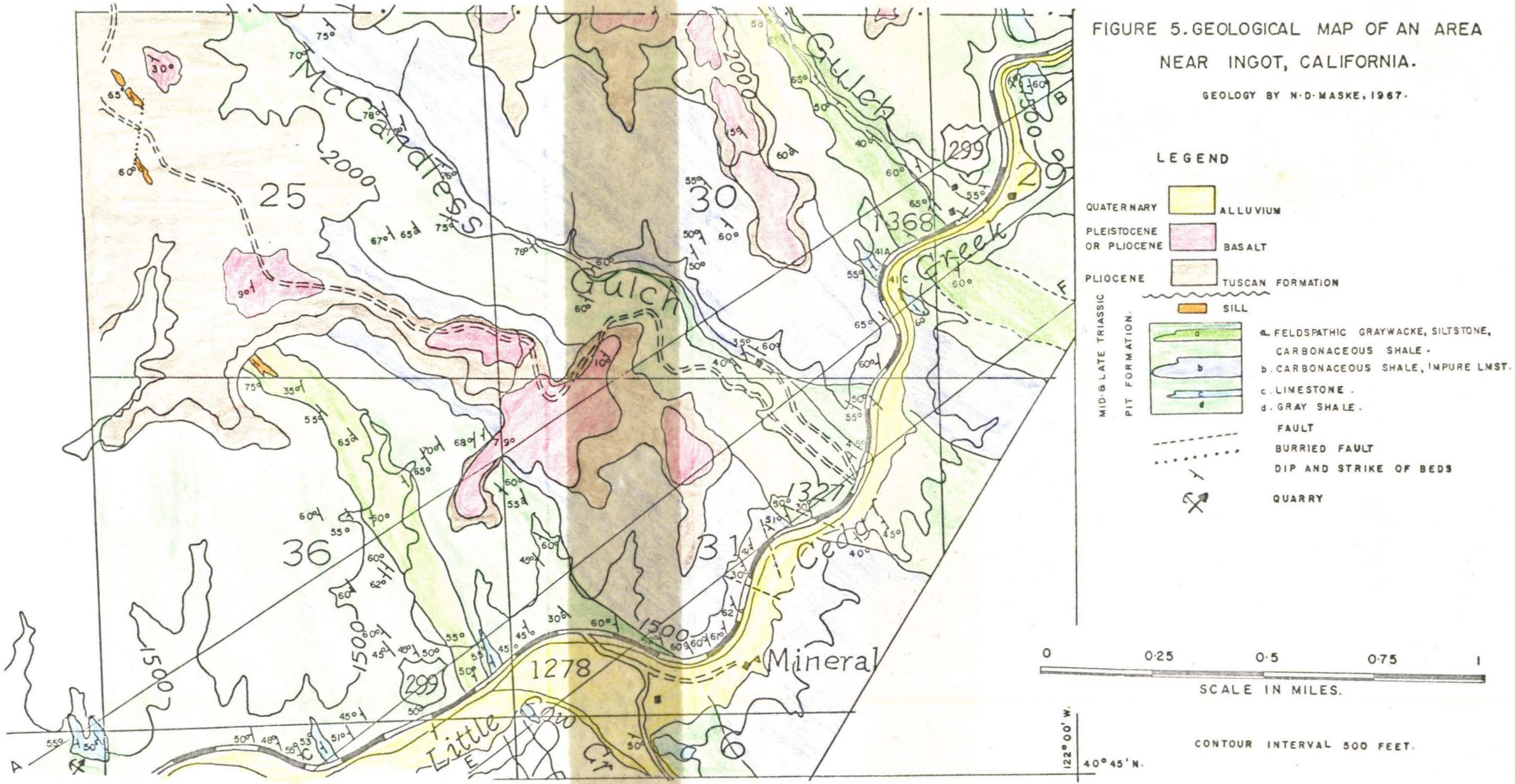
Minor Folds

A number of minor folds were found, most of which appeared to have been produced by drag effects, since they are encountered in the softer weak shales bordered on either side by undeformed beds. Minor fold axes plunge either northwest or southeast at angles between 20° to 50°.

The amplitudes and wave lengths are variable, ranging from about one foot to several feet.

FIGURE 5. GEOLOGICAL MAP OF AN AREA NEAR INGOT, CALIFORNIA.

GEOLOGY BY N·D·MASKE, 1967.



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Major Fold

The area seems to represent a major isoclinal fold for the following reasons:

1. The repetition in reverse order of rocks of similar lithology on either side of an assumed axis.

2. The presence of the current bedding near location 34 indicates inversion of beds, but a graded bed points to a normal attitude at the same place.

3. Absence of major faults to cause repetition of beds.

It was impossible to ascertain whether the repetition was due to an anticlinal or a synclinal folding. There is no attempt to use symbols for overturned bedding on the map, although about half the Pit bedding probably is overturned.

Albers and Robertson (1961) mapped an anticline in the southeast part of their area. The projection of that fold into this area would be along the axis of the fold in question. It becomes reasonable to assume that the present area too has an anticlinal structure (Fig. 6).

In both areas the folds are asymmetrical, but whereas in the other area the fold is not overturned, in the area under investigation the fold is overturned.

Faults

No fault in the area is large enough to cause appreciable displacement of the rocks. However, there are several small high-angled faults. Between locations 1 and 8 three small faults strike between N 20° W and N 68° W, and range in dip from 70° to 77° southwest. Apparently, another fault dislocates the basaltic andesite sill in the extreme

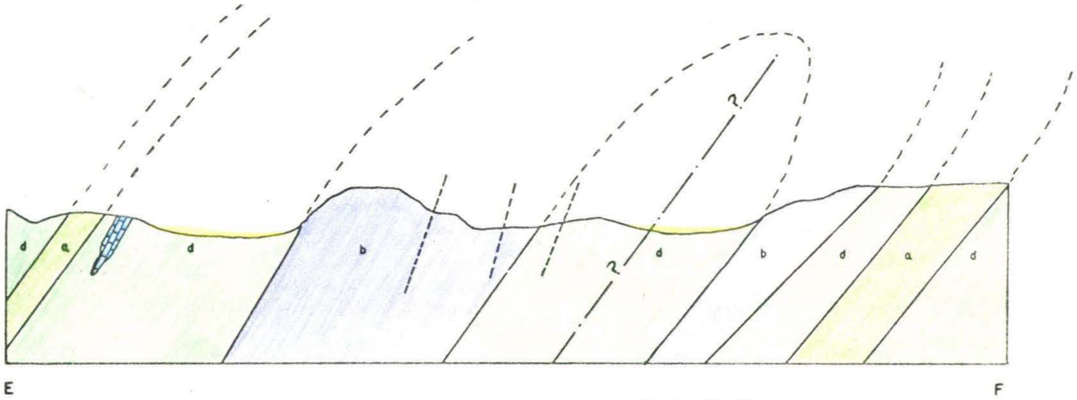
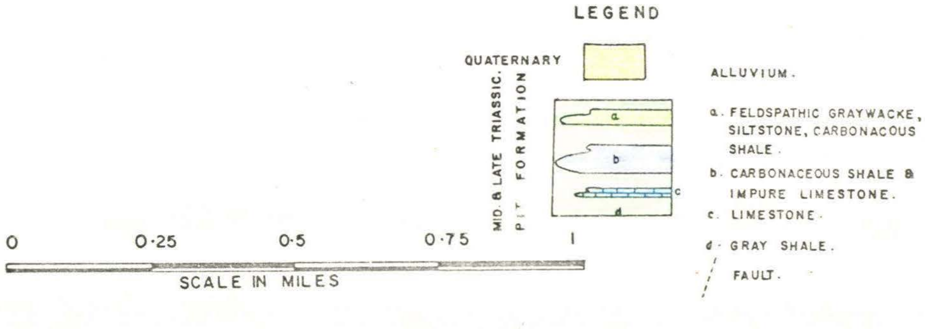


FIGURE 6. GEOLOGICAL SECTION ALONG E-F.



northwestern corner of the area. That fault strikes N 7° E, but its dip could not be ascertained. Bedding and fault planes are nearly parallel in most cases, and there is a general lack of definite marker units, so it was difficult to determine the amount of displacement on any of the faults. The criteria used for fault recognition include: (i) abrupt change of dip and strike of beds, (ii) presence of water seepages, (iii) clear-cut breaks in the continuity of visible bedding, (iv) occasional presence of quartz-cemented breccia. Some fault planes are marked by slickensides.

Unconformity

There is a marked unconformity between the deformed rocks of the Pit Formation and the overlying Tuscan Formation. It has a gentle slope towards the southwest.

Another erosional unconformity probably separates the Tuscan Formation and the later basalt.

Age of Deformation

Within the mapped area the deformation can be dated no closer than between the Late Jurassic and the Pliocene. However, the main deformation is believed to have taken place during the Nevadan Orogeny of Late Jurassic and Early Cretaceous age, because in adjacent areas all the pre-Late Cretaceous rocks have suffered the same degree of deformation (Albers and Robertson, 1961, p. 53).

PETROGRAPHY

SHALES

There are two types of shales present in the area.

Black Carbonaceous Shale

Megascopic Character: These are black dense shales with slightly developed fracture cleavage. Most grains are of silt size, but range from fine silt.

Microscopic Character: The rock consists of from 30 to 40% feldspar, mostly oligoclase. The grains are angular to subangular, and range in diameter from 0.005 to 0.08 mm., few clasts being much bigger. It was difficult to determine the composition of the finest grains.

Quartz occurs only in traces. Lithic fragments consist of silt-sized volcanic and chert grains. The chert occurs in oval or spherical bodies (0.03 to 0.06 mm.) that probably represent remains of fossils (20-25%). No definite organic structures could be seen, but perhaps recrystalization of the silica has destroyed any organic structures that were once present. In some carbonaceous black shales these spherical objects were absent.

The matrix consists of very fine grained ferruginous and carbonaceous material together with tuffaceous material. Pyrite dots and cubes, hematite flakes, and threads of limonite make up about 2% of rock.

The carbonaceous material is present in the form of black to brown cloudy masses that occasionally coalesce into larger elongated bodies parallel to bedding. In this way a rough schistosity is developed.

There is as much as 4% chlorite, but generally its abundance is about 1 to 2%. Traces of sericite occur.

Calcite replaces feldspar and occurs as cement in amounts as great as 20%, although the abundance of calcite in some rocks is very little.

Medium Gray Chloritic Shale

Megascopic Characters: When they are fresh the shales are medium gray to olive gray. They are soft and are at places highly sheared. These shales are laminated and have a tendency to weather easily to a yellowish gray color.

Microscopic Characters: The constituent minerals are arranged in laminae parallel to the bedding which impart a fissile character to the mass. One of the main distinguishing features of the rock is its lack of calcite; secondly, the content of carbonaceous material is very low compared to the other shales. Ordinarily the shale consists in most part of a fine textured base in which truly detrital elements are embedded.

The detrital minerals consist mainly of angular fragments of oligoclase, making up from 15 to 26% of the rock. Most of the feldspar grains are clear or slightly cloudy and are untwinned. Some, however, are clear, and show albite and Carlsbad twinning. Some of the untwinned grains were found to be albite, by study of refractive index in oils. The feldspar grains ranged in size from 0.02 to 0.08 mm.

About 0.5 to 5% of the rock is quartz in clear angular grains that show undulatory extinction. Some grains are composite with sutured contacts. The grain size ranges from 0.005 to 0.65 mm. The lithic fragments chiefly consist of oval to ellipsoidal grains of chert and some volcanic fragments, ranging in size from 0.005 to 0.06 mm. The quantity of lithic fragments is from 10 to 23% of the rock. Some specimens contain shreds of white mica.

The groundmass of the rock is mainly light brownish-yellow fibrous chlorite that totals about 20 to 40% of the rock. Finely comminuted feldspar (15-23%) and fine shreds of sericite (1 to 8%) are also abundant. Probable lithic grains, altered glass streaks, blebs of hematite and limonite, and subordinate amounts of calcareous material also are present. The chlorite, limonite, and other components form streaks and subparallel layers that define the bedding of these shales.

The sedimentary sequence in the area probably is part of the Pit Formation of Middle to Late Triassic age (Smith, 1927). Though most of the rocks were unfossiliferous, there were some fossiliferous horizons. Two fossils from locality 34 were identified by Dr. J. M. Resig as _Halobia superba_ Mojsisovics and _Pseudomonotis subcircularis_. They indicate Late Triassic age for the shales containing them. If the interpretation shown in the structure section is correct, these should belong to the youngest part of the section.

FELDSPATHIC GRAYWACKE

These are sandstones containing angular unsorted fragments enclosed in a finer matrix.

Megascopic Character: The rocks are light to dark gray, medium- to coarse-grained sandstones that occur in beds one to four feet thick, interbedded with dark gray to black, thinly-bedded carbonaceous shales, black dense massive thick beds of siltstones, and in certain cases, thin lenses of limestone. The sandstones are dense and hard and contain pyrite.

Microscopic Character: The texture is typically clastic, showing detrital ~~subhedral to anhedral~~ angular to subangular grains of plagioclase feldspar, lithic fragments, a little quartz, and grains of calcite formed by replacement of feldspar grains. The matrix consists of volcanic and ferruginous silt and there is a secondary calcite cement.

The feldspar is mostly oligoclase of the composition Ab 15 to Ab 24. A few grains of andesine were seen. ~~A~~Oligoclase was found to constitute from 30 to 63% of the rock, determined by thin section point count (300 points on each of the nine sections) (Fig. 7). The feldspar grains are angular to subangular and often are nearly tabular to rectangular. They range from 0.002 to 1.8 mm in diameter. Most of the grains show albite and Carlsbad twinning, but some are untwinned. The grains are relatively unaltered and clear, save some of the clasts that have been partially or wholly replaced by secondary calcite. The extinction angle X': (010) varies from 16 to 18° and the optic axial angle varies from 78° to 86°, negative or positive. Calcite averages from 1 to 20% of the rock.

Lithic fragments are the next most abundant component, averaging from 13 to 42% of the rock. These grains are conspicuously more rounded than the feldspar and quartz clasts, probably because they are more easily abraded. Most of the lithic fragments are volcanic, mostly basalt and andesite, and probably some tuff and altered volcanic glass. Fine-grained chert, commonly with sutured contacts, makes up about 1 to 2% of the rock. Some of the chert may be recrystallized. A few shale pieces are seen.

Quartz makes up from 0 to 3% of the rock. A few angular to subangular, clear grains appear to be detrital. Some grains have minute

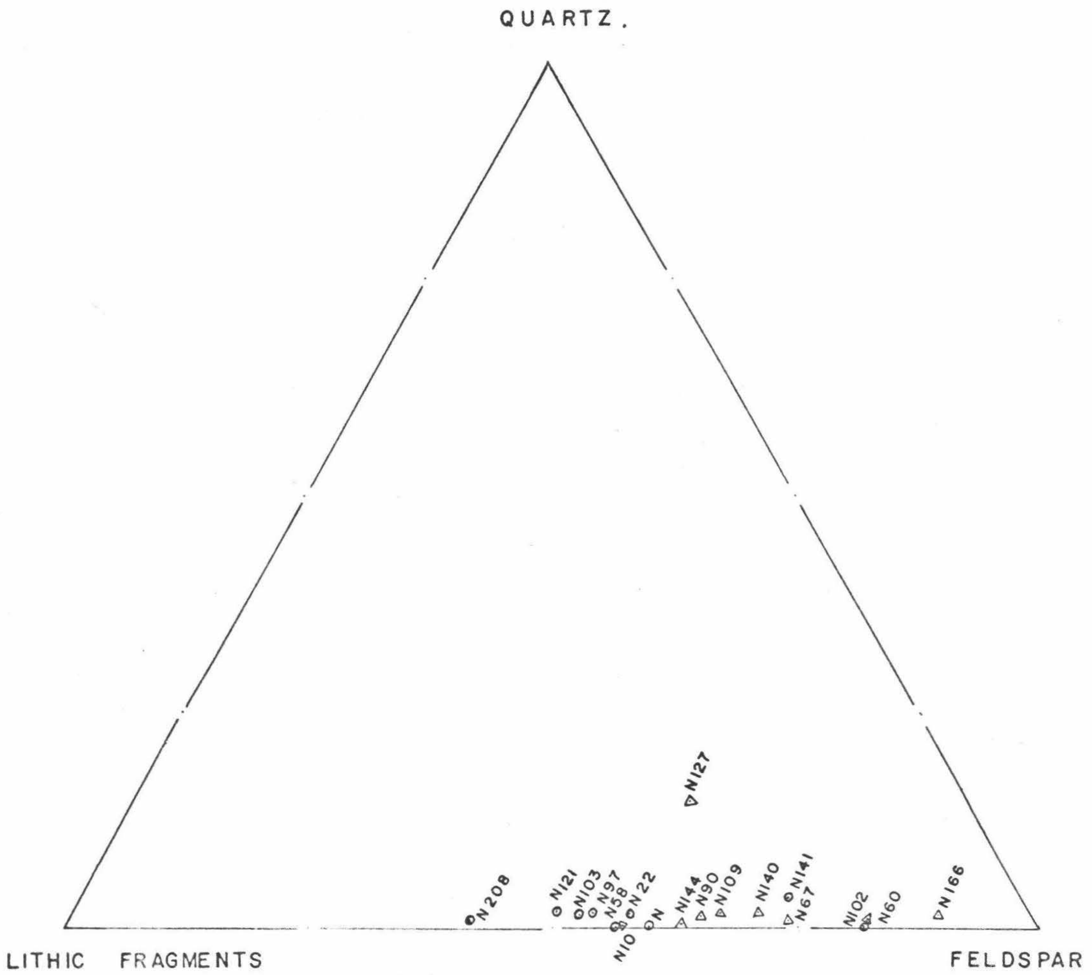


FIGURE 7. TRIANGULAR DIAGRAM FOR SANDSTONE & SILTSTONE.

cracks. A few rare euhedral grains were found. Grains range from 0.02 to 0.75 mm in diameter. Most grains of the quartz are characterized by undulatory extinction, showing that they are strained. Others are composite, consisting of several crystal units separated by sutured boundaries.

Matrix makes up 5 to 15% of the rock, usually about 8%, and consists of altered glassy volcanic material, ferruginous material, and in some cases traces of chlorite (1 to 2%), formed probably due to alteration of glassy material and clay.

Pyrite occurs as irregular blebs and cubes, generally lying between clasts, and makes up about 2 to 5% of the rock. Under reflected light it appears brass yellow. Grains range in diameter from 0.005 to 0.63 mm. The pyrite probably is secondary in origin. Hematite and limonite stains are common, probably due to alteration of the pyrite. Other accessory minerals present are rods of apatite included in feldspar, and in some rocks a few grains of zircon.

SILTSTONE

Dark gray to black siltstone is a massive rock occurring in beds 3 to 5 or more feet in thickness interbedded with gray feldspathic graywacke sandstones rich in volcanic lithic fragments and cleavable grayish black to black carbonaceous shales. (Some have referred to this rock as "argillite"). They are, however, traversed by joints normal to the bedding which break them up into smaller blacks. They consist of very fine sand to coarse silt. Weathering makes them yellowish-brown, probably due to coloration by limonite released by alteration of minute pyrite crystals which they contain.

Microscopic Characters: Under the microscope the thin sections show that the siltstone is composed mostly of very fine sand- to silt-sized grains. The clastic grains are angular. A small portion of the rock (about 30%) consists of slightly bigger clasts set in the matrix of smaller clasts. In general, the rock constitutents are similar to those of the sandstones, except that the siltstones contain a slightly greater amount of feldspar together with conspicuous brownish-black streaks and blebs of carbonaceous matter between the detrital grains.

The feldspar is almost exclusively oligoclase, as in the sandstones. The grains are angular to subangular and range in size from 0.005 to 0.065 mm, rarely as big as 0.08 mm. The characteristic properties are similar to those in the sandstones. The feldspars compose from 40 to 70% of the rock. Replacement of feldspar by calcite is seen in some cases.

Quartz makes up from 0 to 1% of the rock. The grains are angular, and show wavy extinction. They range in size from 0.02 to 0.065 mm.

The lithic fragments consist of volcanic material and significant amounts of oval cherty grains. They make up between 6 and 30% of the rock, the size ranging from 0.02 to 0.85 mm in diameter.

The matrix content varies from 9 to 15% consisting mostly of carbonaceous material, ferruginous material and altered glass. The carbonate content, in the form of replacements and cement, appears to be high, averaging from 0 to 25%. No distinct bedding or micaceous laminae are present in the matrix, but a certain rough alignment of alongated particles, apparently shards, was noted. Pyrite makes up from 3 to 6% of rock, occurring as grains between the detrital grains.

As in the sandstones, the pyrite is secondary in origin. Laucoxene is present in small amounts.

LIMESTONE

One of the most striking features of the limestone occurring in this region is its small areal extent. The thickness at various places varies from 50 to 150 feet. Along Highway 299, six prominent exposures of limestone are encountered. The study of these reveal that there are three types of limestones present (Figs. 8 and 9).

Microcrystalline Allochemical Pelletal Limestone

This falls under type II of R. L. Folk's classification (Folk, 1962).

Megascopic Characteristics: These are hard, light to medium-gray limestones which are occasionally traversed by calcite veins.

Microscopic Characteristics: Pellets, intraclasts, and fossil fragments are set in a fine-grained microcrystalline matrix. Pellets occur as ellipsoid masses or as ovoid and spherical forms. These are aligned sub-parallel to bedding and they are seen to swing around grains of intraclasts, probably a result of compaction of the sediments.

Some of the bigger pellets have sparite replacing them. Subhedral and anhedral intraclasts average about 15% of the rock and range in size from 0.006 to 3.0 mm in length. Fossil fragments, which could not be identified, make up about 2 to 3% of the rock. Secondary quartz as cavity and vein fillings, and albite feldspar make up about 2% each of the rocks. Pyrite and limonite are subordinate blebs and dots.

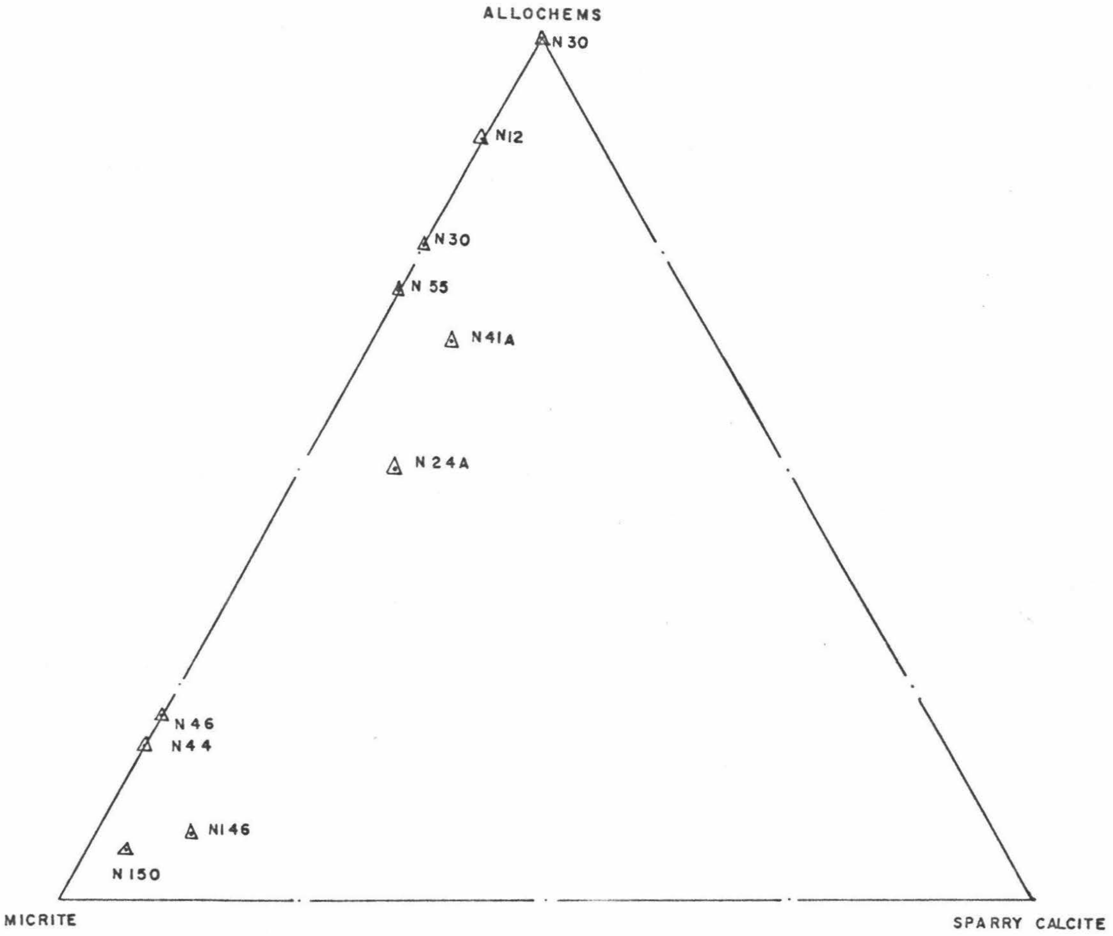


FIGURE 8· TRIANGULAR DIAGRAM FOR LIMESTONE

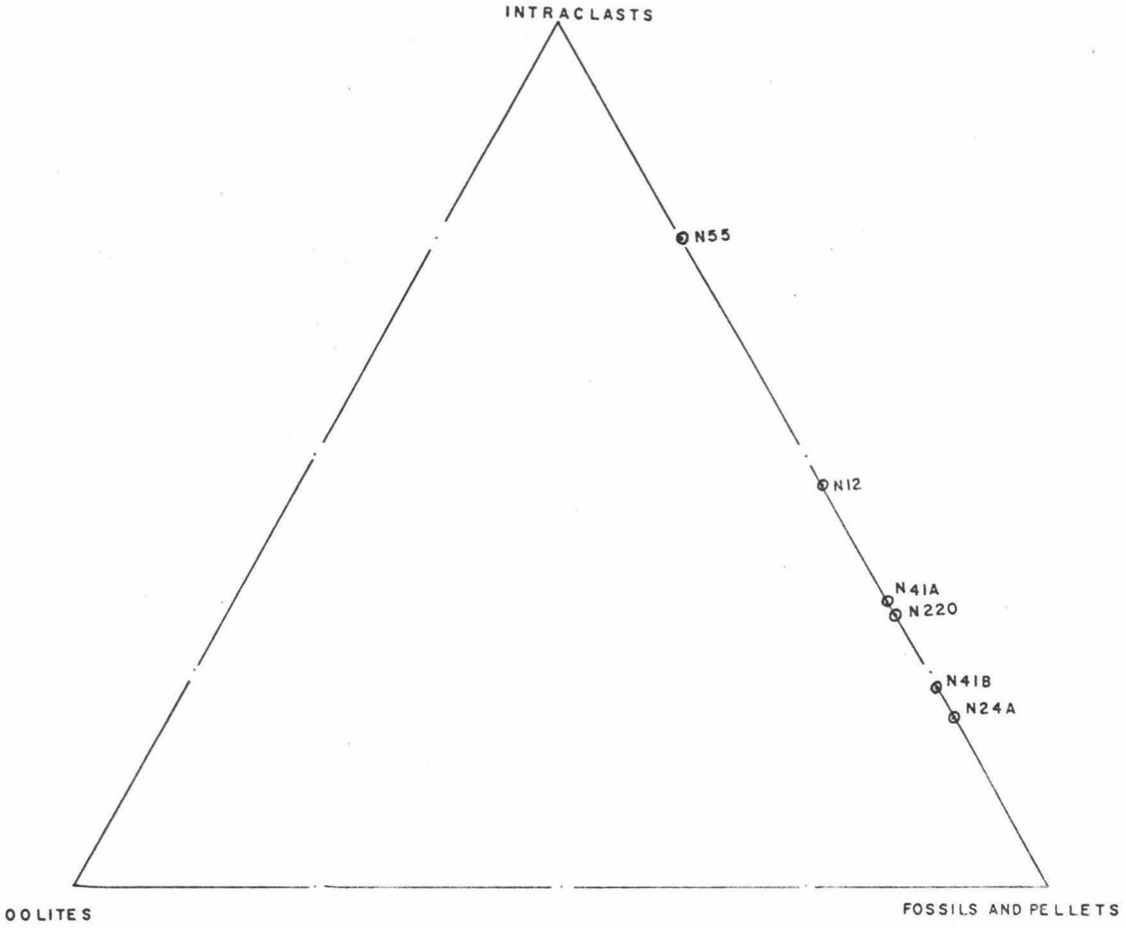


FIGURE 9· TRIANGULAR DIAGRAM FOR ALLOCHEMS IN LIMESTONES

Microcrystalline Intraclastic Limestone

In hand specimen this looks just like the limestone described above.

Microscopic Characters: Under the microscope it is characterized by clasts of limestone 0.05 to 2.3 mm imbedded in a microcrystalline matrix. The intraclasts make up from 40 to 75% of the rock, and fossils make up 15 to 35%. Lithic fragments, mostly basalt and andesite, make up about 5% of the rock. There are some dark brown carbonaceous streaks. Quartz, oligoclase, and iron oxides are present in insignificant amounts.

Sample number 30 A is a typical example in which 75% of the rock consists of clasts set in a microcrystalline matrix (24%). The section is extremely clear except for about 1% of pyrite and limonite.

Micritic Carbonaceous Impure Limestone

Megascopic Characters: These are thinly bedded, dark-gray limestones which have been highly sheared. These limestones are found with carbonaceous shales, and are not mapped separately from them.

Microscopic Characters: The rock consists of very finely laminated pelletal material (about 15%) in a microcrystalline calcite laminated with dark brown streaks of carbonaceous material. Due to shearing, the rock has been foliated and thrown into small scale folds forming anticlines and synclines. In some cases the fine lamellar structure has been disrupted and broken. The micrite amounts to 65% to 70% of the rock, and the carbonaceous material makes up approximately 15%. Pyrite and lithic fragments make up about 1% each, the lithic fragments include chert and volcanic material.

X-ray diffraction was carried out on specimens number 201, 209, 212, and 24. These peaks showed 20 values for Cu K radiation from 29.43° to 29.64°, indicating magnesium-poor calcite.

Diller (1906) correlated these limestone lenses with the lithologically similar Hosselkus Limestone of Late Triassic age. The limestones mapped during this present work might be correlatable to the Hosselkus Limestone because some of them are associated with the fossiliferous Late Triassic gray shale. However, they could not be traced to known Hosselkus Limestone outcrops, and so for convenience they are included within the Pit Formation as used in this present mapping.

The lenticular character of the limestones is probably due to limitations in the conditions of deposition because the lenses gradually thin to an edge regularly parallel to the bedding, and are enclosed by shales. Shales also occur between lenses of limestones. The lenticular forms could not have been produced by displacement and removal of the intervening portion by faulting, as no such faults were detected. No major fault is present along Little Cow Creek, since the limestone beds on the two sides of the valley are not noticably displaced in relation to each other.

The rocks appear to have been deposited rather rapidly in areas of weak and short-lived currents. This is substantiated by the presence of micritic matrix which could not be winnowed away, and lack of sparry calcite. The pellets in the limestone may represent fecal pellets of organisms that lived in the calcareous muds when they were being deposited, or they may have been formed by a process of accretion, whereby fine particles of micritic material adhered to each other during alternate periods of transportation and deposition.

TUSCAN FORMATION

The rocks of the Tuscan Formation consist of friable tuff, conglomerate and arkosic sandstone. The conglomerate is composed of well-rounded pebbles that range mostly from 1 to 8 inches in diameter, the majority being about 2 inches. Some boulders as big as 5 feet in diameter, were seen. The pebbles are made up of basalt, fine-grained igneous rock, quartzite and other rock types. The matrix consists of arkosic sandstone with clay matrix, cemented by iron oxide. On weathering, the conglomerates are reddish-brown because of coating of the pebbles with iron oxide stain.

Sandstones are buff colored and weakly consolidated. In thin section the grains are subangular and subrounded, and poorly sorted. Feldspar forms about 30% of the rock and is partly oligoclase (24%) and partly albite (6%). Quartz forms about 22% of the rock, whereas lithic fragments, mostly chert and volcanic material, comprise 10%.

Biotite makes up 5% of the rock. A clay matrix makes up 5% of the rock, whereas calcite cement makes up about 20% of the rock, and hematite and limonite form up to 2%.

VOLCANIC FLOWS

Lava flows are found in isolated patches on hill tops above the Tuscan Formation. All are basalts according to the classification of Williams (in Williams, Turner, and Gilbert, 1954). In general, three types of basalts were recognized, and their characteristics are given on the following page.

Hypersthene Augite Basalt

Megascopic Characters: In hand specimens are medium gray with a conspicuous porphyritic texture. White phenocrysts of feldspar and dark phenocrysts of pyroxene are clearly visible. The rock possesses minute vesicles (0.005 to 0.06 mm) which are usually empty.

Microscopic Characters: The thin section study reveals that the rock consists of about 65% plagioclase (An 60 to An 65), 15% augite and 5% hypersthene. Reddish-brown iddingsite, an alteration product of olivine, makes up another 4% of the rock. Opaque cubes and irregular flakes are of magnetite (5%) and hematite (1%). The remainder of the rock consists of a light brown glassy groundmass.

The texture is porphyritic, with phenocrysts of plagioclase as large as 2.5 mm totaling about 45%. Augite and subordinate hypersthene and iddingsite form other phenocrysts. The groundmass consists of laths of plagioclase, augite, iddingsite, magnetite cubes, and few crystals probably of pigeonite. The latter are characterized by very small optic axial angles.

The plagioclase phenocrysts range in size from 0.5 to 2.5 mm in length and consists of euhedral to subhedral prismatic and lath shaped crystals, many of which are zoned. The cores are slightly more calcic than the rims. Hypersthene occurs in slender tabular prisms and is characterized by marked pleochroism (X-pink, Z-greenish), parallel extinction, biaxial negative sign, and optic axial angle ranging from 60° to 65°. Augite crystals range in size from 0.5 to 1.35 mm.

Porphyritic Olivine Basalt

Megascopic Characters: This is a dark gray porphyritic rock showing phenocrysts of plagioclase and pyroxene, and light greenish specks that probably are an alteration product of olivine.

Microscopic Characters: In appearance the rock is similar to the type described above in that the rock is porphyritic with abundant phenocrysts of plagioclase (An 60-63), making up about 40% of the rock. The total plagioclase makes up about 65% of the rock. Augite forms about 20% of the whole rock and about 7 to 8% is augite phenocrysts. Most olivine is altered to chlorite and iddingsite; in some cases remnants of fresh olivine can still be seen. Olivine and its alteration products makes up about 5% of the rock. Magnetite totals approximately 5% of the rock. The remainder is glass. Hypersthene is conspicuously absent. Traces of apatite as inclusions in feldspar are found to occur.

The phenocrysts of plagioclase range in size from 0.15 to 3.1 mm. Many of the feldspar phenocrysts are zoned with the core more clacic than the rim. Some cores are as calcic as bytonite. Most of the alteration product of olivine is brownish-yellow chlorite, but brownish-red iddingsite also is present. In many cases, the entire olivine crystal has been replaced by a fibrous chloritic material.

Olivine Basalt

Megascopic Characters: It is light to dark gray rock which appears slightly banded due to the presence of greenish alteration material (serpentine) in thin streaks. The rock is fine grained.

Microscopic Characters: The rock is fine grained and microporphyritic, with glomerocrysts of augite and olivine set in a felted microcrystalline aggregate consisting of lath-shaped microlites of plagioclase (An 60-An 63), augite, and some hypersthene and glass. The subparallel plagioclase microlites show flow orientation of a pilotaxitic texture around the glomerocrysts. The plagioclase microlites constitute about 58% of the rock. Augite constitutes about 20-25% of the rock and grains range in size from 0.005 to 0.4 mm. Olivine occurs as lozenge-shaped and prismatic crystals, which in some cases have been partly altered to reddish-brown iddingsite, although other grains remain fresh. The alteration products are greenish serpentine and limonite. In another case, lozenge-shaped crystals of olivine have been resorbed with liberation of magnetite around the border. Magnetite is found segregated throughout the rock and composes 5 to 6% of the whole rock.

The olivine is characterized by parallel extinction, biaxial positive sign, optic axial angle 86° to 88°, and high relief. The augite has optic axial angles between 46° and 60°, with Z angle C about 40° to 45°. Traces of apatite are found as inclusions in feldspar.

As plagioclase is more than twice as abundant as pyroxenes in all these rocks and because plagioclase is slightly towards the calcic side of intermediate plagioclase, the plagioclase probably crystalized earlier (Williams, Turner, and Gilbert, 1954, p. 39). The olivine probably antedates both the plagioclase and the pyroxene.

ECONOMIC GEOLOGY

The present area does not appear to be of great economic value from the standpoint of mineral wealth. Because the limestone is magnesium-poor, it is a potential source for lime products. However, none of the limestone deposits in the area is of sufficiently great extent to be of value for large scale exploitation for cement manufacture. Two small quarries in the northeastern and southwestern part of the area produce crushed limestone for paving roads.

The siltstones, which are hard and compact, are locally used as road ballast. Since the dips are high, overburden is great in all cases.

No traces of ore deposits were detected in the region. The lack of intrusive rocks probably obliterates chances of mineralization being present. However, rocks of the Pit Formation in other areas do contain ore deposits. The easternmost of the copper deposits of the Shasta Mining District lies only four miles to the southwest. The Pit Formation is too severely deformed and impermeable to afford any chance for petroleum.

The area, however, is quite valuable for grazing and timber.

CONCLUSIONS

The area near Ingot, California, represents part of the flank of an orogenic belt. The basement rocks consist of eugeosynclinal sediments that have been isoclinally folded. It could not be determined whether the major overturned fold in the area is an anticline or a syncline; it is interpreted as being an anticline. The sandstones and the siltstones are all quartz-poor rocks, in fact, the area represents an outstanding example of quartz-poor sandstones in eugeosynclines. The detrital sediments are of similar compositions, but present gradations in their texture from sandstone to silty shale. Even in the shales gradation in grain size is seen.

The conspicuous lack of, or low percentage of, quartz points to a source area probably of intermediate rocks. The high percentage of plagioclase feldspar and dominantly volcanic lithic fragments indicate a volcanic source area. The grains are dominantly angular to subangular. Lack of abrasion probably points to a nearby source area. The presence of a high matrix content of the sandstones points to very rapid deposition of the sediments. Except for one sill of unknown age, the lack of lava flows and pyroclestic beds suggest that during the period these rocks were deposited, volcanic activity was absent within the immediate area.

The source of replacement calcite in the sediments may be either: (1) nearby limestone lenses, some of which may be included deep in the sediment layers, (2) calcium liberated by albitization of intermediate plagioclase feldspars in some nearby locality, or, (3) by solution of calcareous fossils contained in the rocks.

The chlorite in shales probably is derived from alteration of ferromagnesian minerals and alteration of volcanic glassy material, or is due to diagenesis of the muddy matrix.

The low grade metamorphism of the sediments is probably a net result of deformation and subjacent igneous activity.

APPENDIX A

MODAL ANALYSIS
Model Percentages for Feldspathic Graywacke

Sample No.	Voids	Quartz	Feld-spar	Lithic Fragments	Calcite	Matrix	(Pyrite) Ore
141		3	63	21	1	7	5
208		0.5	30	42	18	8	1.5
121	2	1.5	38.5	40	8	5	5
22	2	1	45.0	32	6	10	4
58			50	38		8	4
97		1	35	29	18	15	2
103		2	33	30	20	10	5
102			60	13	20	5	2

MODAL ANALYSIS
Model Percentages for Siltstone

Sample No.	Quartz	Feldspar	Lithic Fragments	Calcite	20	Others
90	1	58	30		10	1
10		40	30	20	7	3
140	1	45	18	25	8	3
144		43	25	18	10	4
60	0.5	70	15	1.5	9	4
67	0.5	51	17	12	13.5	6
166	1.0	55	6	3	15.0	20
35		15	30	22	20.0	13
109	1	42	20	20	10.0	7

MODAL ANALYSIS
Model Percentages for Limestone

Sample No.	Intraclasts	Pellets	Fossils	Micrite	Sparite	Others
41B	18	55	5	15	6	1
220	12	25	2	57	4	
41A	20	39	1	25	8	7
24A	10	38	2	40	9	1
12	40		35	10		15
55	45		15	25		15
30A	75			24		1
146	3.5	3		82.5	10	1
150		5		90.0	4	1
55	45		15	25		15
44		15		70		15
46		18		67		15

PLATE 1

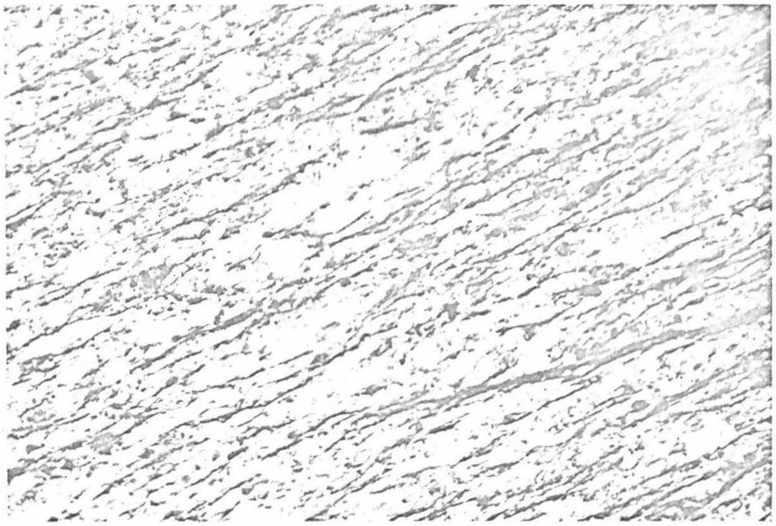


Figure 1. Grains of unsorted feldspar, lithic fragments and quartz are arranged in a subparallel fashion in a ferruginous clayey matrix with streaks of chlorite and limonite. (x 28.7)

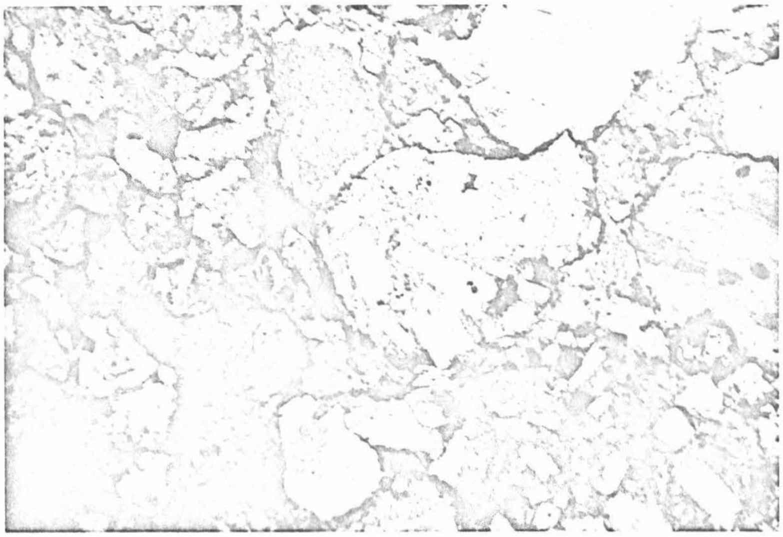


Figure 2. Subangular unsorted volcanic lithic grains, feldspar and shale in a ferruginous clayey matrix and replacement calcite. (x 28.7)

PLATE 2

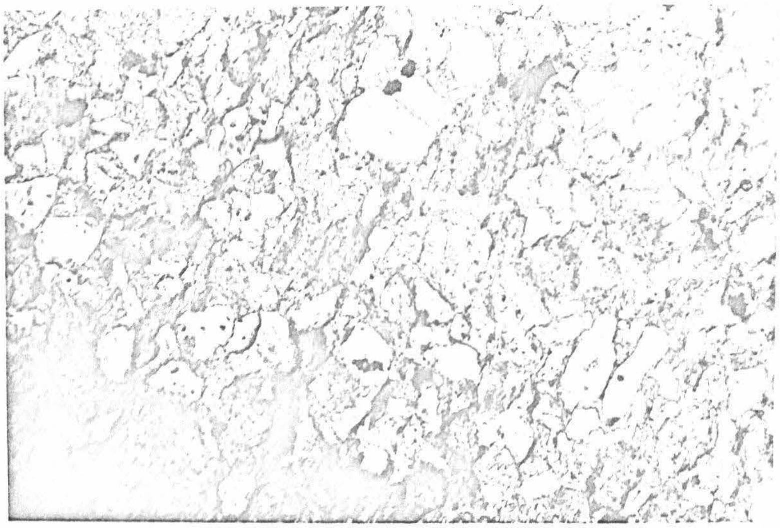


Figure 3. Unsorted subangular to angular grains of oligoclase, replacement calcite grains, lithic volcanic fragments and quartz in a coarse siltstone. (x 28.7)

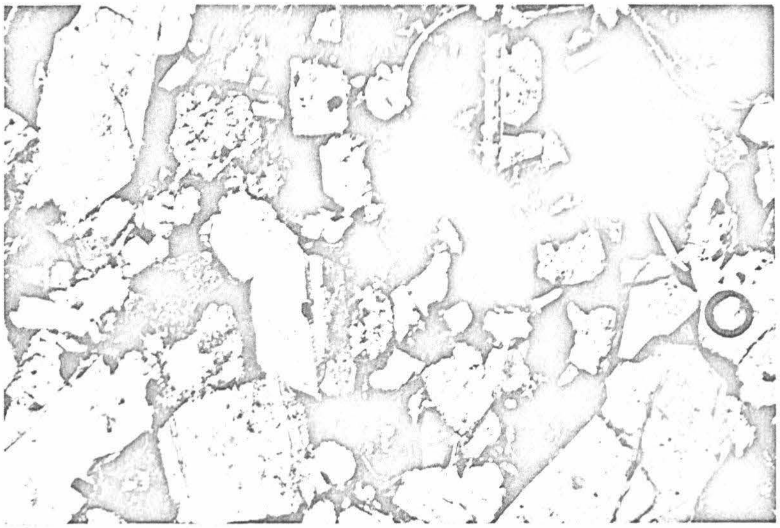


Figure 4. Angular unsorted grains of oligoclase, volcanic lithic fragments, and chert in a ferruginous clayey matrix. Nicols crossed. (x 28.7)

PLATE 3

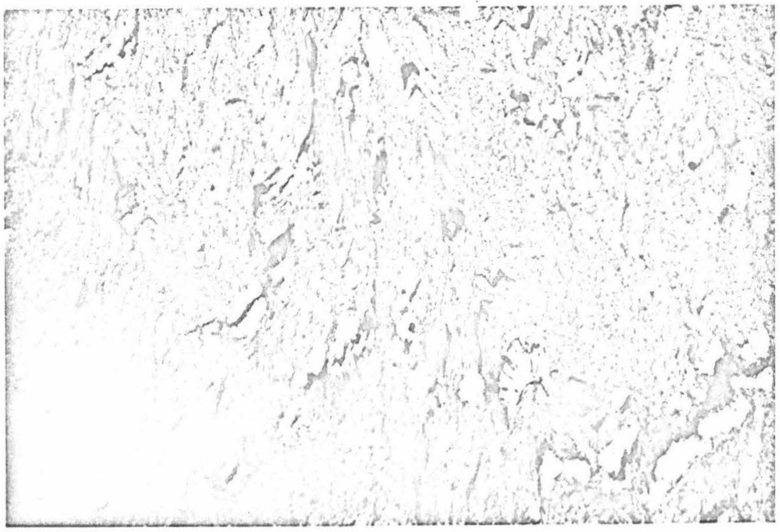


Figure 5. Fossils and intraclasts in a micritic matrix. (x 28.7)

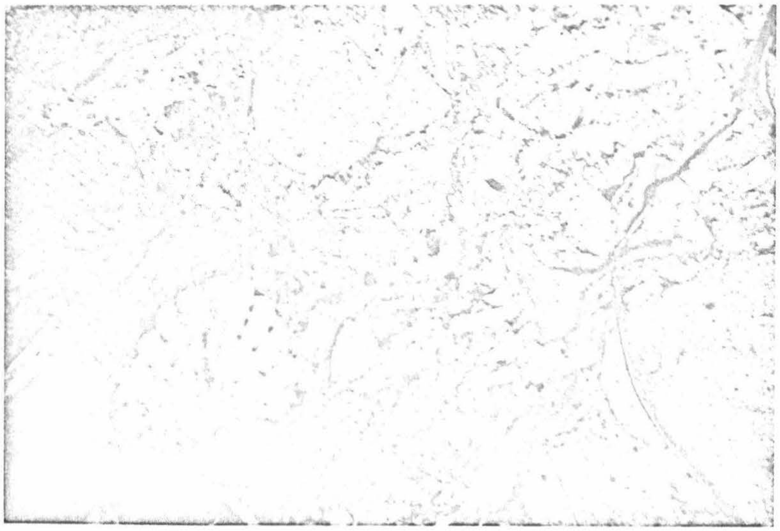


Figure 6. Micritic deformed limestone. The thin layers are thrown into folds, the openings in which have been occupied by sparite cement and chalcedony. (x 28.7)

PLATE 4

Figure 7. Calcite intraclasts in a micritic matrix. (x 28.7)

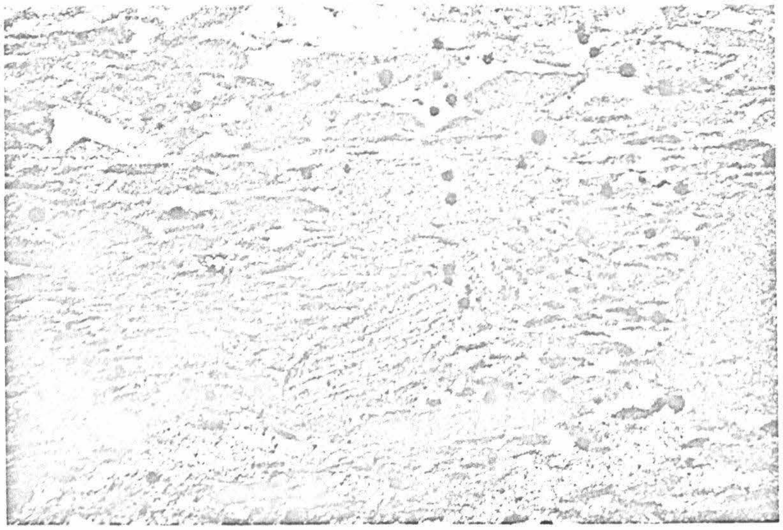


Figure 8. Swinging of pellets around calcite intraclasts in a micritic matrix. (x 28.7)

PLATE 5

Figure 9. Microporphyritic basalt containing phenocrysts of lozenge-shaped crystals of olivine partly altered to iddingsite, in a felted microcrystaline aggregate. (x 65)

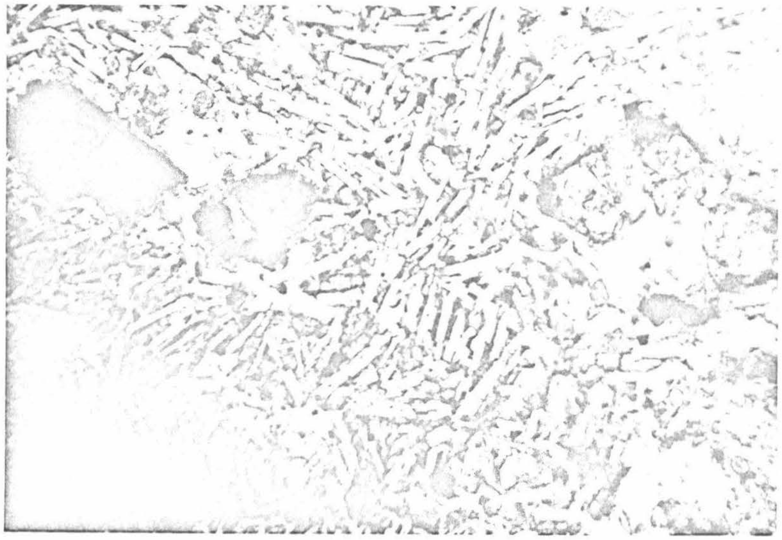


Figure 10. Microporphyritic basalt containing phenocrysts of olivine which have been partly resorbed with the liberation of magnetite, in a groundmass of labradorite and augite. (x 28.7)

BIBLIOGRAPHY

Albers, J. P. and Robertson, F. F., 1961, Geology and Ore Deposits of East Shasta Copper-Zinc District, Shasta County, California: U. S. Geological Survey Professional Paper 338, 102 p.

Anderson, C. A., 1933, The Tuscan Formation of Northern California with a Discussion Concerning the Origin of Volcanic Breccias: University of California Publications in Geological Sciences, V. 23, p. 215-276.

Billings, M. P., 1957, Structural Geology, 2nd ed., Englewood Cliffs, Prentice Hall, 514 p.

Diller, J. S., 1893, Cretaceous and Early Tertiary of Northern California and Oregon: Geol. Soc. Am. Bull., V. 4, p. 205-224.

__________, 1895, Lassen Peak Folio, California: U. S. Geol. Survey Geol. Atlas of the U. S., Folio 15.

__________, 1906, Redding Folio, California: U. S. Geol. Survey Geol. Atlas of the U. S., Folio 138.

Fairbanks, H. W., 1893, Geology and Mineralogy of Shasta County: California Min. Bur. Rept. 11, p. 24-53.

__________, 1894, Notes on Some Localities of Mesozoic and Palezoic in Shasta County, California: Am. Geologist, V. 14, p. 25-31.

Hinds, N. E. A., 1933, Geological Formations of the Redding Weaverville Districts, Northern California: Calif. Jour. Mines and Geol., V. 29, p. 76-122.

__________, 1933, Mesozoic and Cenozoic Eruptive Rocks of the Southern Klamath Mountains, California: Univ. of Calif. Bull. Dept. Geol. Sci., V. 23, p. 313-380.

Pettijohn, F. J. and Potter, P. E., 1964, Atlas and Glossary of Primary Sedimentary Structures: New York, Springer-Verlag, 370 p.

Smith, J. P., 1894, Metamorphic Series of Shasta County: Jour. Geol., V. 2, p. 588-612.

Whitney, J. D., 1865, Geology of California: Calif. Geol. Survey, Vol. 1, p. 325-329.

Williams, H., 1932, Geology of the Lassen Volcanic National Park, California: Univ. Calif. Dept. of Geol. Sci. Bull., V. 21, p. 195-385.

__________, Turner, J. T. and Gilbert, C. M., Petrography an Introduction to the Study of Rocks in Thin Sections: San Francisco, W. F. Freeman and Co., 386 p.