SENOR THESIS

GEOLOGY OF MOUNT PINOS AREA, VENTURA COUNTY

by

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Table of Contents

Abstract 1

Introduction 3

Purpose of Investigation 3

Method of Investigation 4

Acknowledgements 4

Previous Studies of the Region 5

Geography 6

Stratigraphy 10

General 10

Igneous Rocks 12

Pinos Granite 12

Sedimentary Rocks 14

Escondido Formation 14

Seymour Sandstone 15

Blue Shale 16

Red Clay 17

Pinos Arkose 17

Plush Formation 19

Miocene Formations 22

Stauffer Basalt 22

Middle Creek Sandstone 24

White Conglomerate 26

Terrace Gravels 27

Alluvium 28

Table of Contents (continued)

Structure	28
General	28
Folding	30
Bitter Creek Fold	32
Faulting	33
Lockwood Fault	34
Basalt Fault	35
Pinos Fault	35
Granite Fault	37
Geomorphology	38
Flat-topped Mountains	38
Terraces	38
Streams	39
Geologic History	39
Economic Considerations	40
Water	40
Gold	41
Borax	41
Rotary Mud	44
Literature Cited	46

Abstract

This paper is written on the geology of the northern half of Lockwood Valley, which is located in northern Ventura Coutny. The area in general is mountainous, and includes Mt. Pinos (8826 feet) as its highest peak.

The rocks consist of two igneous member (granite and basalt) and many sedimentary ones (shales, sandstones, and conglomerates). The oldest rock is granite intruded in the Jurassic. This is overlain by a series of continuous, marine sediments of Eocene age. These are overlain by a basalt flow which was extruded in early Miocene times. Both marine and terrestrial beds of the same age overlie the basalt. The only subsequent deposits are of terrace gravels and alluvium.

Faulting is the most prominent type of structure. Folding is present, but plays a very minor part on the area studied. There are two sets of faults, one running concentrically about the other radially to Mt. Pinos. The second set is of little importance. The first set, is made up of four large faults, which uplift sediments and granite along the southern side of Mt. Pinos.

From an economic standpoint this is a place of both recent and historical interest. The region was one of the first localities in which borax was mined (1899), and mining was continued intermittently until 1913. Gold

has been taken in large quanities from the southern side of Lockwood Valley since the early 1880's. At the present time the area has a new business in the mining of rotary mud. This is done by steam shovel from one of the valley's many clay beds.

Introduction

Purpose of Investigation

This thesis was written to complete part of the requirements for a bachelor's degree in geology. The work was done under the direction of Dr. John H. Maxson, Assistant Professor of Geology at the California Institute of Technology. The field work was in the greater part done during the summer of 1939, but supplementary field work was continued on into 1940.

The region that was mapped is located in Mt. Pinos Quadrangle in the extreme northern part of Ventura County. This area is triangular, being bounded by the Ventura-Kern County line on the north, the Lockwood Valley road on the south-east, and a north-south line running from Mt. Pinos to the Lockwood Valley road on the west. Mt. Pinos is in the north-westerly corner of the section.

The area is reached from Pasadena by taking Foothill boulevard to U. S. 99. U.S. 99 is followed through Castaic, up the ridge route, through Gorman, and over Tejon Pass about a mile and a half. Here Frazier Mountain road is taken going to the west through Frazier Mountain Park seven miles to Chuchupate Ranger Station, where ~~you~~ it enters the north-eastern part of the area. This road continues down Lockwood Valley and over into Cuyama Valley, and is the main path of travel. Additional roads are found branching off it going to the two public camp grounds on

Mt. Pinos and up North Creek a small way. Most of the roads represented on the U.S.G.S. map, printed in 1903, are at the present out of use. Those in Lockwood Valley are in fair condition except in the rainy season.

Method of Investigation

The mapping was done with the aid of a Brunton compass on an enlarged section of the U.S.G.S. map of Mt. Pinos Quadrangle. This section was enlarged four times. The scale of the field map was 1/31,250 and the contour interval was one hundred feet. This map was highly unsatisfactory when it came to detailed work, therefore, the two cross sections taken on Middle and Bitter Creeks were done by pacing along the canyon bottoms and mapping the contacts in separately.

Acknowledgements

Chuchupate Ranger Station — The author gives much thanks to its rangers for the loan of their fire cabin on Mt. Pinos for his convenience during the summer and for the aid extended to him in getting acquainted with the area.

Mr. Plush (ranger on North Creek)	Mr. Plush also helped to acquaint the author with the region and allowed him to pass freely over his land.

Previous Studies of the Region

This area was covered previously by C. Lewis Gazin in his Doctor's Minor Thesis, "Geology of the Central Portion of the Mount Pinos Quadrangle (Ventura and Kern Counties, Southern California)", at the California Institute of Technology. The present area done was but a small section of his total survey, which due to the greater amount of area covered was not done in as much detail.

H.S. Gale (1912) described the borate deposits in this section when they were in operation. *

H.W. Fairbanks made a brief reconnaissance of this area in 1894, but this report is too short to be of much value.

* References to authors referred to are found in the back under Literature Cited.

Geography

The area is located in northern Ventura County at an elevation of about 5000 feet in Lockwood Valley and rising up to 8826 feet at the top of Mt. Pinos. The whole area slopes up towards this flat-topped mountain, which is a great block of granitic material wedged up between the San Andreas Fault on the north and the Mt. Pinos Fault on the south. From this mountain may be viewed all of Lockwood Valley (Fig. 1). The whole area may be seen from the long ridges running from the sides of Mt. Pinos out into the valley (Fig. 2) to the divide in which Lockwood Creek disappears in the far distance. Several prominent fault features are noted from this elevation, such as the fault ridge and valley seen in the left foreground of Figure 1.

Mount Pinos is the highest peak in the region, and as such controls the drainage. From Mount Pinos rain water has a four-way dividing point: to the south-east it flows down Lockwood Creek to Piru Creek, and finally into the Santa Clara River; to the east ~~the~~ water runs down Cuddy Canyon into Castaic Lake; to the west the water flows down Cuyama Valley and enters the ocean near Santa Maria; and to the north the drainage is by way of the San Joaquin Valley. The creeks in the area radiate from Mount Pinos. Material cut through with exception of the

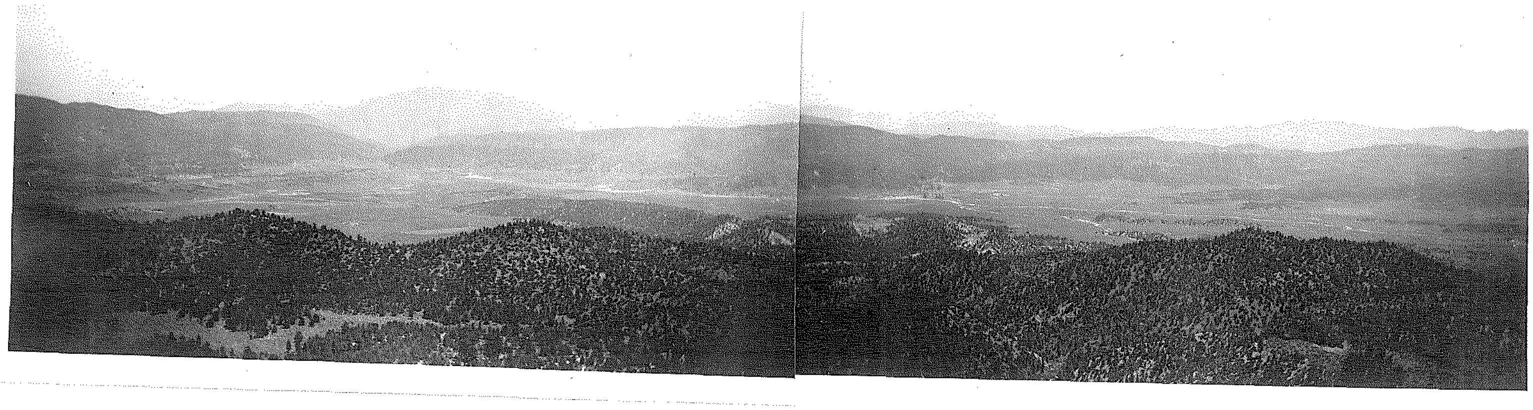

Fig. 1 Looking out across Lockwood Valley from the side of Mt. Pinos. Lockwood Creek disappears in the far distance. In the left foreground is a small fault valley formed by the Basalt and Pinos Faults.

main granitic block and a narrow strip of arkose (Fig. 8) is soft, so that the streams have cut rapidly in an attempt to reach grade. At the contacts of the softer sediments with the harder materials are found falls ranging up to 150 feet in height (Fig. 3). The creeks are usually dry in the summer time, and they flow about nine months a year. August and September are the dryest months. There seems to be quite a bit of seasonal variation. In 1919 to 1922 the region had wet years, this was followed by a slump in the amount of rain until the last few years, when the rainfall increased and the creeks flowed longer in the summer time.

The region as a matter of topography might be broken into three parts: the flat alluviated areas, the low ridges running up to the granitic contact, and the higher mountain mass. Each of which is characterized by a different type of vegetation. The flat alluviated areas are sparsely covered with low brush. In the low hills we have Piñon pine, manzanita, mountain mahogany, and scrub oak as the chief covering. The higher altitudes are covered with tall Jeffry pines and a few white firs. Throughout the whole area brush is usually rather scarce, and one is not hampered to any great extent by the vegetation.

Rock exposures are often bad. This is due both to

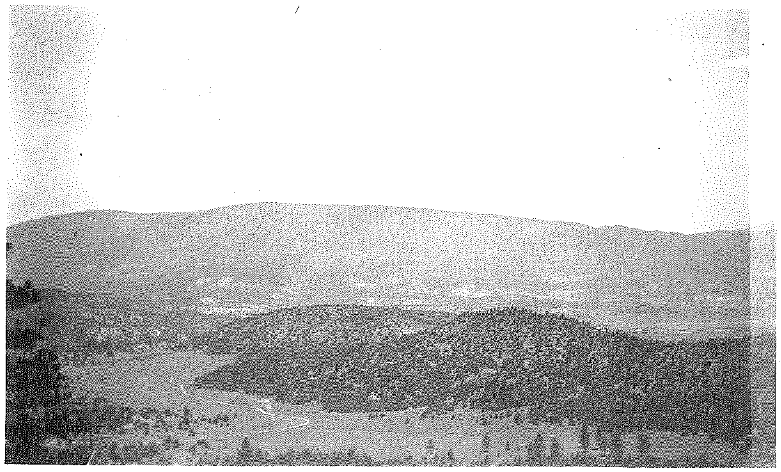

Fig. 2 Looking along the fault valley near Seymour Creek from Mt. Pinos. The Basalt Fault follows the curve of the hills in the foreground.

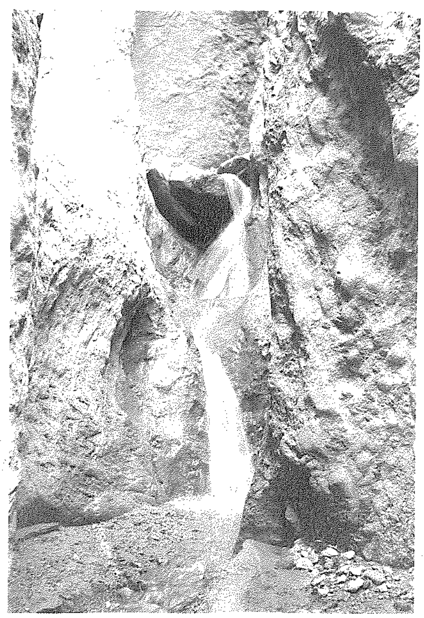

Fig. 3 The lower part of the falls in the Pinos arkose on Middle Creek.

the great amount of talus and the character of the sediments. The granite has a very coarse texture. This makes it an easy prey of weathering, and the talus from it covers the ridges to the depths of several hundred feet. Basalt has practically no fresh surfaces as it weathers easily to form a fine powdery dust which slides down the mountain sides and hides the bed rock. Most of the sediments have a certain amount of clay, which is quite susceptible to weathering. This causes the sediments to gully and to erode easily. Terrace gravels also aid in hiding underlying formations. However all the exposures aren't bad. Creeks have cut through the alluviated covering and give excellent exposures along the canyon sides. Several large erosion basins expose the White conglomerate in picturesque badlands, and the granite has many good outcrops.

Stratigraphy

General

The rocks of the area consist of a number of sediments and a few igneous members. Granite, which is thought to be of Jurassic age, makes up the main block of Mt. Pinos and is the oldest rock in the region. This is followed by Eocene sediments made up of sands, shales, conglomerates, and silts. In this conspicuous formation, the Escondido, is found a prominent band of arkose, which serves as a marker bed. The individual beds in the Escondido are numerous ranging from a few inches to several hundred feet in width and consist largely of sands. Only the larger and more important beds were put on the map as the others were too numerous and too small to be illustrated. Oligocene beds may be present in the upper part of the series, but no definite proof has been unearthed on this question. The above mentioned sedimentary beds are marine, and are overlain by a Miocene lava flow. This flow is of varying thickness and trends with the rest of the beds to the north-east. Marine Miocene beds are lying on top of the lava. A gap appears next in the series where several later marine beds are not visible in this area. The next known formation is a white, terrestrial, Miocene conglomerate, which is underlain to the south of the region mapped by a fine clay used for rotary mud. All these formations are overlain spottally by terrace gravels and recent alluvium.

To sum it up we start off with igneous granite. This is followed by sedimentary, marine, Eocene rocks. Basalt lies on top of this, and the other sedimentary rocks are marine Miocene and terrestrial Miocene, which are covered in places with terrace gravels and alluvium.

Igneous Rocks

Under this heading we will discuss the Pinos granite. The Stauffer basalt will come in its proper stratigraphic position.

Pinos Granite

The norhtern part, especially the north-western part of the area, is made up of granite. It is a great block that forms the main body of Mt. Pinos. It was for this reason that the name Pinos granite was selected. It rises above all the other rocks and being more resistant than them to weathering it forms high falls at its contact with other rocks. Outcrops are good (Fig. 4).

This great mass of granite varies considerably in texture. Near the top there is a grey, medium-grained rock, which as you progress farther down the sides of the mountain becomes coarser and coarser until some of the orthoclase crystals are an inch in length. The color changes from grey to pinkish. The coarser grained granite seems to be by far the most common. It is made up chiefly of pink orthoclase, quartz, and a little dark biotite (about 6%).

This rock has been intruded into gneiss, as a few small patches are found on the tops of some of the ridges. These seem to be roof pendants of an older formation. The granite is a block that is brought into its present

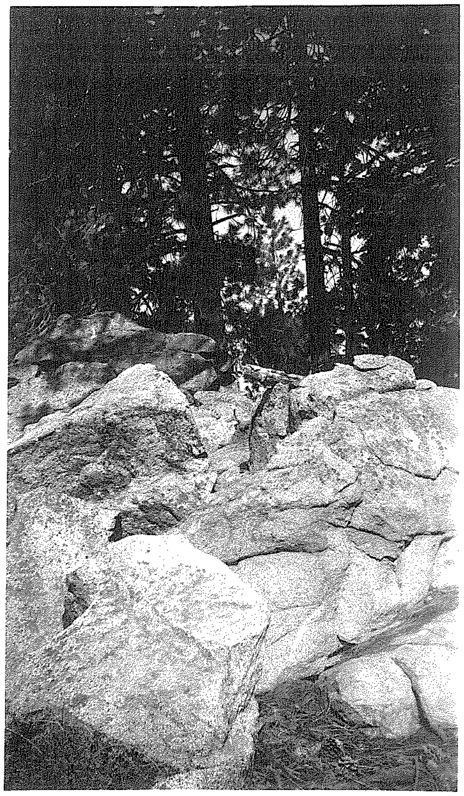

Fig. 4 A typical exposure of granite near the top of Mt. Pinos.

Fig. 5 One of the few outcrops showing primary basalt in place.

position by faulting. It is bouded on the south side by The Pinos Fault and on the north by the San Andreas. It is probably Jurassic in age. Correlation is difficult, but this granite seems to be of similar age as that described by Walter A. English in Cuyama Valley and on Pine Mountain.

Sedimentary Rocks

The sediments are chiefly clayey sands and shales of Eocene and Miocene age. The Eocene sediments are separated from the Miocene by a flow of early Miocene basalt.

Escondido Formation

The Escondido is a name Kew gave to an Oligocene formation near Santa Maria. It is felt that this formation correlates with at least the upper part of the formation found in the Pinos area, even though the beds in the lower part of this conformable series are of known Eocene age. This formation contains many hundreds of beds ranging from a few inches to several thousand feet in thickness. Of these beds only several of the more important were mapped in separately. The Escondido formation is divided into the Seymour sandstone, the Blue shale, the Red clay, the Pinos arkose, and the Plush formation. The Plush formation is made up of the upper part of the Escondido formation and consists of many beds, mainly sandstones. In its western portion it has Pinos arkose interbedded in it.

A very badly preserved fossil was found on North Creek in the Blue shale, which indicated that it was marine. C. Lewis Gazin in his work on Reyes and Beartrap Creeks in the same formation found fossils which showed the beds were clearly Eocene.

Seymour Sandstone

The Seymour sandstone is found on a ridge to the north of Seymour Creek. It does not occur any where else in the section as it is cut off by the Pinos Fault to the west and disappears under terrace gravels to the east. The true thickness of this sandstone is unobtainable, as it is cut off by a fault, but of the amount exposed there is a thickness of about 1,750 feet. The sandstone is made up of coarse sand grading in places up to a small pebble conglomerate. It has prominent outcrops on the Seymour Creek side of the ridge. These are in the form of great jagged blocks of rock tilted about 60 degrees to the south. The sandstone appears to be made up mainly of quartz particles.

The Seymour sandstone is bound on the north by the Pinos Fault and on the south it has the Blue shale lying conformably upon it. Its age is lower Eocene, as it lies conformably below the Blue shale in which early Eocene fossils were found on Reyes Creek by C. Lewis Gazin.

Blue Shale

The Blue shale lies directly to the south of the Pinos Fault except north of Seymour Creek where the Seymour sandstone appears. Like all the other members of the Escondido formation it has a north-easterly trend. This rock is a coarse blue shale, and weathering has changed the color from a dark blue to a light brown and destroyed the trend of the beds by making a network of innumerable small fractures. All these seams are colored with iron oxide. This covers the true bedding and gives the rock an appearance of being highly incompetent (Fig. 6). The weathered zone is usually several feet thick decreasing inwardly. Fresh surfaces are found only at the bottom of the canyons, where the streams remove the weathered particles.

The thickness of the Blue shale is hard to calculate, as it is cut off by a fault on most of its northern boundary; however, on Middle Creek a thickness of 1000 feet was measured. The Blue shale is bound on most of its northern boundary by the Pinos Fault. On its south the red clay lies conformably on it. Gazin correlated this formation with the Eocene on Beartrap and Reyes Creeks (Turitella uvasana).

Red Clay

The Red clay lies conformably on the Blue shale, and is found to the south-east of it. This rock is made mostly of clay with a little grit, and shows brillant shades of red when wet. Though the greater part of the clay is red, there is some that is blue and green. In general it is a very colorful rock. Weathering quickly bleaches it and makes it hard to distinguish except along the sides of some of the canyons, where erosion is swift (Fig. 7). This bed has more lateral variation, both in texture and color, than the Blue shale. It is a bed about 450 feet thick and lies conformably between the older Blue shale on the north and the younger Plush formation on the south. As the Blue shale is Eocene it is assumed to be of this age.

Pinos Arkose

The Pinos arkose is a prominent bed extending from the western boundary of the area to the west side of Bitter Creek, where it lenses out. This bed is a good marker for part of the area, as it is resistant to weathering and forms high cliffs (Fig. 8). The arkose is named Pinos arkose because it is made up of granite of the same type as found on Mount Pinos. It has the same large, pink orthoclase crystals, and the same relative amounts

Fig. 6 A typical outcrop of Blue shale showing the effects of weathering.

Fig. 7 An exposure of Red clay along Bitter Creek.

of other minerals. It resembles the Pinos granite in every respect. In North Creek the stream has eaten through it without changing grade, while in Middle Creek it forms a falls of about 125 feet in height.

The Pinos arkose is on the average about 100 feet thick. It is a strata bounded conformably above and below by the Plush formation. It is a lens wholly within this formation, and because of its prominent marker position is given a separate describtion.

Plush Formation

The Plush formation was named after a rancher on North Creek, near whose ranch some excellent exposures are found. This formation lies to the south of the Red clay, and is uplifted on its southern side by the Lockwood Fault. It is made up of many beds. Most of these are sands, but there are quite a number of shale, and a few of conglomerate. The beds are of variouss thicknesses ranging from several inches to many feet. Clay seems to be a common constituent of the sandstones and shales. The beds nearest the Red clay formation have more clay than most of the other strata.

At the upper end of the formation, near the Red clay boundary, the beds are dipping 75 degrees to the south, and near the Lockwood Fault, far enough back to discount drag, they are dipping only 10 degrees south. The beds have been gently bent and near the southern boundary one bed, due to flattening, is exposed for some distance. Where the strata is thus flattened, a beautiful facies change may be seen. Near the Lockwood Fault we have a tightly cemented conglomerate. As one travels north along the creeks the boulders in this stratum diminish in size until the rock finally becomes a sandstone, which in turn becomes very clayey before the bed disappears. Also in the southern part of the section the conglomerate and sandstone are massive and form resistant cliffs (Fig. 16). These are often carved by erosion into many peculiar shapes (Fig. 9 and Fig. 10). As you follow this stratum to the northward, it becomes less resistant until it forms gently weathered slopes similar to those of the Red clay. This facies change shows clearly that this particular stratum had its sediment source somewhere to the south-east.

A bed of limy shale is the last bed in the Plush formation. It is overlain by the Stauffer Basalt and contains a large amount of gypsum. It has small limestone beds interbedded with it (Fig. 11 and Fig. 12). These beds are usually highly incompetent.

The Plush formation, itself, is about 3000 feet thick. It is thought to be of Eocene age as it rests conformably

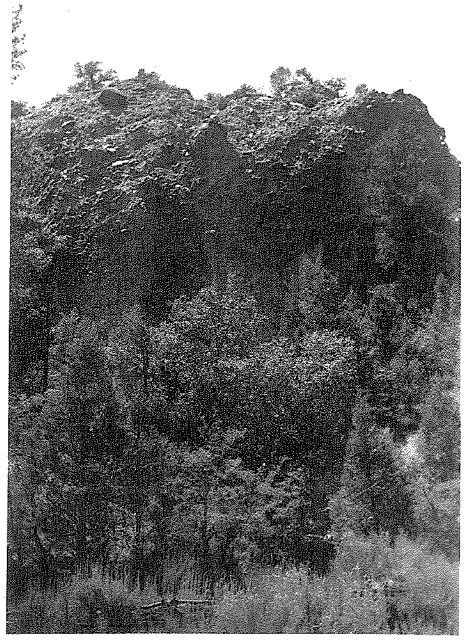

Fig. 8 One of the massive cliffs formed by Pinos arkose. This particular exposure was on North Creek.

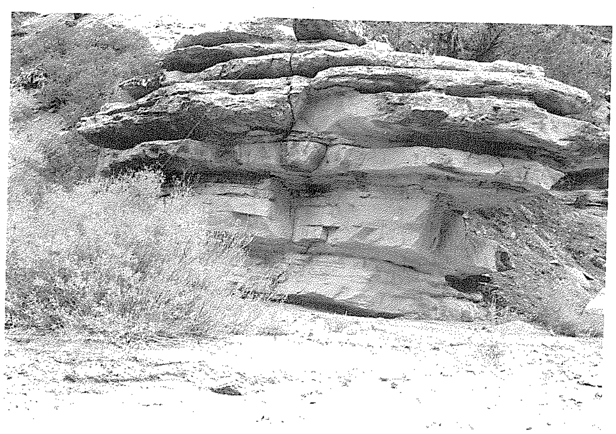

Fig. 9 One of the many queer shapes carved out of the sandstone in the upper part of the Plush formation.

on other Eocene strata. The upper part of it may be Oligocene, though no proof has been found for this theory. It lies conformably on Red Clay . On it lies Miocene basalt. There must be an unconformity between the two, though it is pretty well hidden by the basalt talus. The whole Escondido formation is uplifted above the valley floor by the Lockwood Fault .

Miocene Formations

On top of the Escondido formation lies the Stauffer basalt. This separates the Eocene or Oligocene sediments from the later Miocene ones. The latter are of two types: namely, early Miocene, marine sandstone and late Miocene, terrestrial conglomerate. Between the two is a space in which intermediate beds are found in the region to the west, but are not exposed in the area covered.

Stauffer Basalt

The Stauffer basalt was named by C. Lewis Gazin after the Stauffer Borax Mine, which is drilled in this basalt. This basalt is a lava flow found lensed in between sediments and varies considerably in thickness. In general it is between 200 and 600 feet thick, being thickest near Frazier Borax Mine. It is found capping the ridge that has been uplifted by the Lockwood Fault, and has a north-easterly trend. It disappears in the eastern part of the area under granitic debris, but is found again

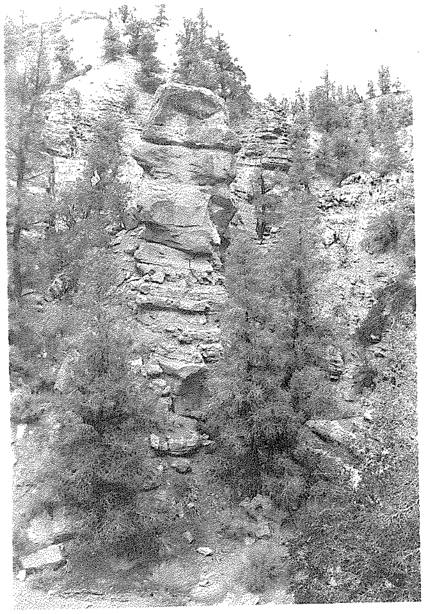

Fig. 10 A weathered pillar of sandstone from the Plush formation near the mouth of Middle Creek.

Fig. 11 Showing one of the many tight folds in a band of limy shale at the top of the Plush formation.

on the south side of Cuddy Canyon.

Outcrops are poor (Fig. 5), becauses the basalt weathers easily to form a fine powdery dust which slides down the slopes to cover other formations with an accumulation of talus. A thin section of the rock shows that it is about 90% labradorite and 10% olivine. It is filled with cracks which are discolored by limonite. The rock is vesicular in places and on top of the ridge to the north of Frazier Borax Mine amygdales of zeolites are found.

The basalt is probably lower Miocene in age. It has lower Miocene sediments above it and Eocene sediments below it. The unconformity between it and the underlying Eocene beds is hidden by a powdery talus. This may invite some doubt to whether it may be upper Eocene in age, but lower Miocene seems to be more likely because volcanic flows in neighboring regions are of this age. (See Walter A. English - 1916 - and H.W.Fairbanks - 1894 -.).

Middle Creek Sandstone

To the west of Middle Creek and to the east of North Creek we find a gray sandstone lying on the Stauffer basalt. This sandstone is fine-grained and has a well-baked appearance. It is fairly hard and by no means crumbly as most of the other sandstones in this region are. It is only found on one ridge,as erosion has removed

Fig. 12 A narrow band of limy shale, which is the top member of the Plush formation, as seen on Middle Creek.

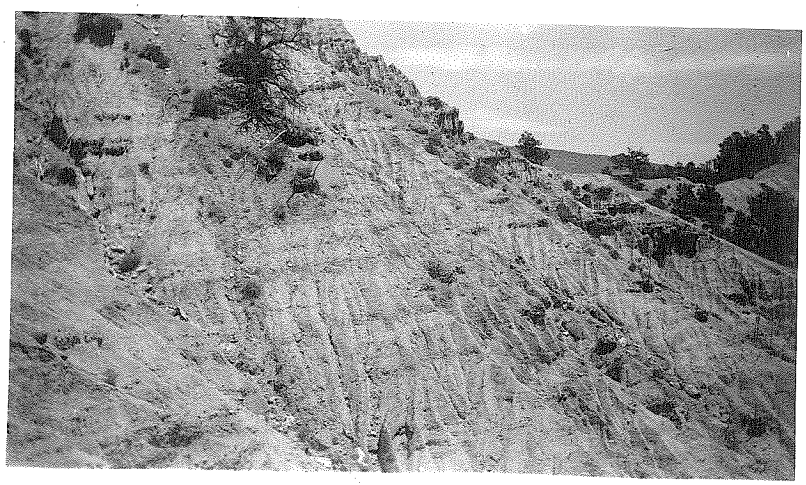

Fig. 13 White conglomerate. Crude stratification may be seen in this view, as it exposes the terrestrial formation in badlands to the east of Middle Creek.

it from the rest. Due to this its true thickness is unknown. That measured was 300 feet. The Middle Creek sandstone lies on the Stauffer basalt. Subsequent beds have been eroded away, leaving no contact of the two. This rock is probably lower Miocene in age, as it lies on lower Miocene basalt and has conformably on it farther to the west strata with Miocene fossils. (Walter A. English (1916) reports on Pectin crassuaido, Turritella ocoyana, Panopea estrellanus.)

White Conglomerate

To the south of the Lockwood Fault in the south-eastern part of the area are a series of low lying ridges. These ridges range up to two or three hundred feet in height, and are made up wholly of White conglomerate (Fig. 13). This rock is crudely stratified and in many places badlands are formed (Fig. 18). These are caused by erosion, and along the sides of the ridges their are often formed great fluted wash basins (Fig. 15). The conglomerate is white in color and contains pebbles of many kinds. Granite and basalt are the chief ones present; however, quartz, chalcedony and pegmatite are also found. The conglomerate is often quite clayey. The sediments probably came from the north, as that is where both the basalt and granite have their primary sources.

This rock varies considerably in hardness, being quite friable in some places and hard in others. The White conglomerate has been eroded away on its upper surface, so its true thickness is hard to calculate. The thickness measured was about 300 feet. To the south of the area it is found lying on Lockwood clay, a rock that has a commercial use as rotary mud. It is covered in places unconformably by terrace gravels and alluvium.

The beds are terrestrial. Proof of this lies in the following facts: the materials of the strata are heterogeneous, no sorting; badlands are developed, due to some parts being soluble and some not; the beds are massive, no clean cut stratification; and innumerable bone fragments are found. The rock is clearly younger than the Stauffer basalt, as it contains cobbles of the latter. C.Lewis Gazin found Miocene fossils in similar beds in the Cuyama Valley.

Terrace Gravels

Several small ridges along Seymour Creek are made entirely of terrace gravels (Fig. 17). Many other hilltops have thin coatings of them. Terrace gravels cover the whole north side of the large ridge north of Seymour Creek. To the north of Bitter Creek in the southern part of the area the White conglomerate disappears under them. Several other ridges have their crests coated with terrace gravels.

The terrace gravels are made up of various sized boulders and a certain amount of earth. Some of the larger boulders must weigh several tons. The age of the terrace gravels is not known, but it was laid down after the White conglomerate and is probably Pleistocene or Recent in age.

Alluvium

Alluvium is found in the broad valleys and along the narrow canyon bottoms. To be considered along with alluvium is granitic debris, which is made wholly of granite particles. This debris is sometimes over a hundred feet thick, and may be measured where the streams cut through it in forming deep canyons. Almost the whole north-eastern part of the area is covered by this debris. It is separated from the regular black, valley alluvium on the map.

The age of the alluvium is Recent.

Structure

General

The Lockwood Valley area has most of its deformation in the form of faulting. This is what one would expect, as it is only a few miles south of the great San Andreas Fault. This fault runs just to the north of Mt. Pinos through Cuddy Valley. Folding is not found frequently in the area and is limited to one small fold seen in the terrestrial White conglomerate and local drag folds caused by faulting.

The faulting might be divided into two systems: first, faults running generally concentric to Mt. Pinos; second, faults radiating from it. The first system of faults is vastly more important than the second, and contains all of the large faults in the area. The second consists of smaller faults, which have at the most several hundred feet of displacement. Starting from the Lockwood Valley and traveling north up the slopes of Mt. Pinos one crosses four fairly large faults belonging to the first system; two of which are responsible for most of the topography in this region. The first fault encountered is the Lockwood Fault. This raises the Eocene beds into view, and elevates them some eight hundred feet above the valley floor. Lockwood Fault is the northern boundary of Lockwood Valley. A mile or so farther up the slope the Basalt Fault is met. The displacement on this fault is small, amounting to only several hundred feet. The name was chosen because in many places it is the northern boundary of the Stauffer basalt. On continued traveling up the mountain one comes to the contact of the Eocene sediments with the Jurassic granite. Here is the Pinos Fault. It is one of the largest faults in the area having a displacement of several thousand feet. It brings the old Jurassic granite from the depths to the height of some 3800 feet over Lockwood Valley. The last fault found going up the mountain is the Granite Fault, about one mile north of the Pinos Fault. It has its movement expressed by topographic features in the granite, and has moved several hundred feet. All these faults appear on the western boundary of the map, and can be traced eastward some eight miles or so, where they disappear under alluvium.

Folding

Folding is not of great importance and does not take a conspicuous place among the structural features of the region. Only one small anticline was found in the area. This, the Bitter Creek Fold, is seen in the White conglomerate ridges on either side of Bitter Creek. Other flexing is found to the north of the Lockwood Fault in the Escondido formation. Here the beds are flattened-out by flexing. This is seen in the fact that near the granitic contact the Escondido is found dipping 75 to 70 degrees to the southward. The dip decreases as one goes south toward the Lockwood Fault until it is only 10 degrees southward. At this point it is cut off by the Lockwood Fault. This gentle flexing takes place in a distance of a little over a mile. In the Escondido formation is also found on this flexure imposed secondary flexing. This is caused by drag on the various faults. Drag on the Lockwood

Fig.14 Bitter Creek Fold to the west of Bitter Creek. Note the badlands in the White conglomerate.

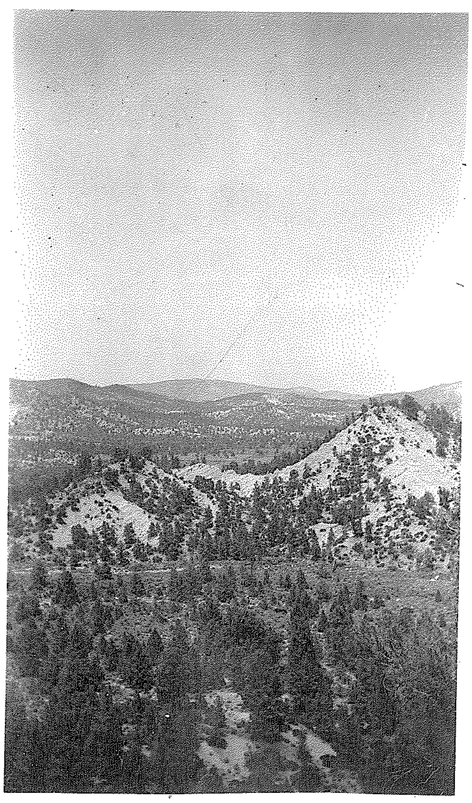

Fig. 15 Bitter Creek Fold looking east across Bitter Creek. The rock exposed is the White conglomerate.

Fault caused the sediments to the north of it to change dip from 10 degrees south to 50 degrees south. To the south of this fault the White conglomerate may be found lapping up on the E ocene formation, where the drag pulled it. Drag is also found along the Basalt Fault. The limy shale found in the upper part of the Escondido is incompetent and becomes highly crumbled along the northern side of this fault (Fig. 12). Just south of it the beds are bent by drag from 17 degrees south to 5 degrees north. This causes a small anticline to be formed on the sotuh side of the Basalt Fault, which is purely a fault feature.

Bitter Creek Fold

The Bitter Creek Fold is a small anticline found crossing Bitter Creek about one mile north of the Lockwood Valley road. It is seen exposed in the White conglomerate badlands on either side of the creek (Fig. 14 and Fig. 15). It runs roughly north-east. The heart of the anticline is eaten out by weathering. This is because in bending the material vertical cracks are formed at the places of greatest tension, which are along the axis of the fold. These cracks give easy access to weathering and erosion takes place. The fold is gentle as the dips to the north are about 10 degrees and those to the south about 10 degrees. It is fairly symmetrical. The fold is only seen in this one place, and disappears both to the east and to the west under alluvium.

Faulting

The faulting is divided into two systems roughly perpendicular to one another. One system runs concentrically about Mt. Pinos, and is reposible for all the topographic changes of any size. In this system there are found four main faults, which have a displacement from a couple of hundred to several thousand feet. On none of them is the strike-slip measureable, as on either side of the faults different beds occur, due to the bringing up of new ones from depth. A minium value is obtainable on the extent of the dip-slip. These faults are all quite steep if not vertical. A beautiful fault valley or graben appears between the Basalt Fault and the Pinos Fault near Seymour Creek, and runs contrary to the regular drainage pattern (Fig. 1). This first fault system contains all the faults of any importance in the region. The second fault system is one that radiates from Mt. Pinos. These faults are found running down the varius creek bottoms. On North Creek a displacement of several hundred feet was noticed at the granitic contact. This displacement decreases as one travels down the creek. The east side of the fault moved northward. No dip-slip was noticed on any of the faults in this second system.

Seymour Creek also has a fault running down it. This fault may have at its granitic contact as much as five hundred feet displacement, which rapidly decreases down stream. There may be faults running down Bitter and Middle Creeks, but no evidences of such were unearthed. The streams tend to follow the lines of weakness caused by the faults. The movements seem to be greates near Mt. Pinos, because the forces probably came through the mountain.

Lockwood Fault

This fault limits the northern edge of Lockwood Valley. It appears in the west and goes across the map to the north-east for some eight miles, where it disappears under alluvium. This fault is resposible for the elevating of the Middle Creek sandstone, the Stauffer basalt, and the Escondido formation to a height of some eight hundred feet or more above the valley floor (Fig. 16). The fault is pretty nearly vertical, and is made up of many small faults. In truth it is a zone of interlocking faults. This is clearly seen just to the west of Seymour Creek, where a fault slice is brought up in this zone exposing the underlying Escondido formation. The true vertical displacement is not known, as the beds between the Middle Creek sandstone and the White conglomerate are not found in this area and hence their thickness can not be measured. However, well over a thousand feet movement is found without counting their thickness. Drag is found to cause considerable bending on either side of the fault (see folding).

Basalt Fault

This fault is found about half way between Lockwood Fault and Pinos Fault. It appears on the western edge of the map and crosses it toward the north-east until it reaches Seymour Creek, which it turns down and disappears. This fault has caused considerable crumbling of the shale along its borders, and is responsible for fair-sized drag folds. The fault is nearly vertical, and the south side went up. Beds on its north side were thus repeated again on its south. The direction or distance of strike-slip was not readily evident. The dip-slip amounts to about 200 feet.

Pinos Fault

The Pinos Fault is found bounding the granitic contact with the Escondido formation, and is with the San Andreas the cause of Mt. Pinos. The area takes a direct rise in topography on reaching the granite and the terrain becomes much steeper. The Pinos Fault appears in the west, crosses the map, and disappears into the north-east into some rather low hills. Being as the granitic debris is here found on both sides of the fault for considerable

Fig. 16 Looking up Middle Creek. The Lockwood Fault cuts across the foreground. The massive cliffs are of the Plush formation.

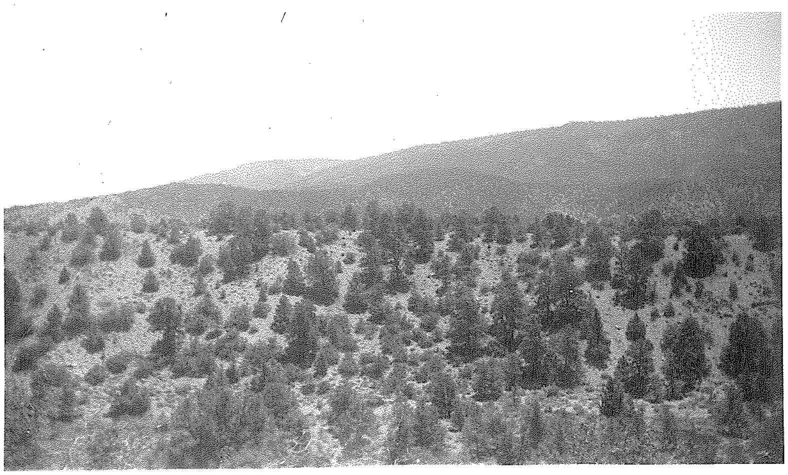

Fig. 17 A low ridge of terrace gravels seen lying to the east of Seymour Creek.

distance, its exact location is impossible to find. The fault dips about 70 degrees to the south, and has raised the old Jurassic granite from the depths to its present height. The true vertical displacement is hard to tell as one does not know the relation of the granite and the sediments originally. The granite has, however, been elevated above the surrounding surface some two thousand feet, and the true displacement is probably much greater.

Granite Fault

The Granite Fault is found about one mile north of the Pinos Fault. It is wholly in the granite. It can be recognized by an offset in the topography . In traveling down any of the ridges off Mt. Pinos in the area, about 2/3 of the way down, the ridges start rising for several hundred feet instead of going down. This is not due to the rock, as it does not change in composition or texture. These changes in topography are found on a line with one another running around the side of Mt. Pinos. The movement on the fault was greatest in the western part of the area, where some 1200 feet vertical displacement was noted. To the east the displacement decreased, and to the north of Seymour Creek only several hundred feet was measured. The dip of this fault was not found, but it is probably almost vertical.

Geomorphology

Flat-topped mountains

The large mountains like Mt. Pinos and Mt. Frazier have large , flat, well-rounded tops. This is noticed quite easily from a distance, as the tops of the mountains look like large, gently-rounded surfaces. Actually several hundred feet from the tops of the mountains flattening begins. Here one encounters open meadows, gently rising knolls with little valleys between them;another knoll somewhat higher may be noticed across a little grassland until the top is finally reached. Mt. Frazier and Mt. Pinos differ only eight hundred feet in elevation. These two mountains with their rather flat tops may be an old erosion surface, formed before the mountains were raised to quite such a great height. As the San Andreas runs along one of the sides of both of these mountains,it might account for the more or less even rising.

Terraces

Terrace gravels cover the tops of several ridges. Along either side of Seymour Creek the terrace gravels form terraces(Fig. 17). Though these gravels are found elsewhere in the region,it is only along either side of this stream that terraces are formed.They seem to be of the same age and slope gently downstream.

Streams

the streams are a direct result of the uplift of Mt. Pinos , and radiate out from it. They are consequent streams. A minor system of faults also radiates from Mt. Pinos. Some of the streams follow these faults as they are lines of weakness. At the contact of the granite with the Escondido formation there is a series of falls, due partly to the up-faulting of the granite, and partly to its being more resistant than the sediments to erosion. These falls average about 100 feet in height. Another large falls is found on Middle Creek (150 feet high) where the stream crosses a band of arkose(Fig.3). This is due to the greater resistance to erosion of the arkose. On reaching the Lockwood Fault no falls are found, as the streams have cut rapidly through the uplifted sediments in an attempt to reach grade(Fig. 16).

Geologic History

The known history of this region starts in the Jurassic, when granite was intruded into some unknown overlying material. The whole area subsided; and the next known change came in early Eocene, when the Escondido formation was laid down in marine waters. During this period of deposition there was a change in the rate of deposition and source of material, causing the variance in thickness and composition of the many beds. In the later half of the Eocene there was an uplift, and the land was not submerged again until Miocene times. In early Miocene we have the country covered by a lava flow, which was followed by submergence and the deposition of marine Miocene beds. Here we have a gap in the area due to beds being not exposed. In late Miocene , however, there was an uplift followed by deposition of terrestrial beds. Except for terrace gravels and alluvium this was the last deposit of sediments as seen in the area at present.

Faultin occurred post-Miocene or started very late in Miocene, beyond which it cannot be fixed in time. The Bitter Creek Fold was also formed after the Miocene Terrestrial beds were laid down. The faulting is a long time feature, and is probably continuing at the present time. There is no record of any subsidence after the one in Miocene times. Terrace gravels were deposited some time in late Pleistocene or Recent. The alluvium is a Recent feature , being formed at the present time.

Economic Considerations

Water

Water is one of the things that Lockwood Valley lacks. Though in winter the rain supply is good, the summers are dry. This makes an otherwise arable land impossible to put to the plow. No water wells have yet been sunk that supply more than enough for domestic needs. Only one ranch(on North Creek) has even partially solved the water problem. This ranch has run a pipe line three miles up the creek and gets its water at the granitic contact, where the water is still on the suffface. Once the water reaches the sediments it sinks into the ground and quickly disappears.

Gold

On the south side of Lockwood Valley in the basement rock of Mt. Frazier gold is found. It was discovered in 1867. In 1895 the Frazier Gold Mine was opened and has since then mined about $1,000,000 in gold(C.Lewis Gazin-1930). Hard rock mining has been the manner of obtaining most of the gold from this region, although placer mining has been carried on from placer deposits since 1881. There has been no gold found on the north side of the valley. The Pinos granite doesn't seem to be a bearer of it.

Borax

In 1898 a prospector named McLaren discovered borax near the present site of Frazier Borax Mine. This borax was in the form of colemanite. Production was started in 1899 and continued until 1907. The colemanite was found mainly in limestome beds interbedded with the basalt. It is this basalt that is responsible for the formation of the colemanite deposits. The borax occurs along with stringers of gypsum in shales below the basalt and in limestones and shales interbedded with it. The latter are the most pro-

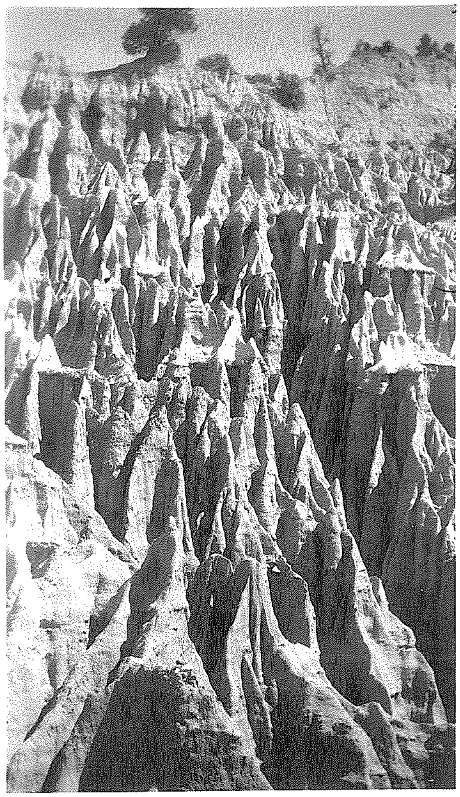

Fig. 18 Badlands. These badlands are found in the White conglomerate to the east of Bitter Creek near the center of the Bitter Creek Fold.

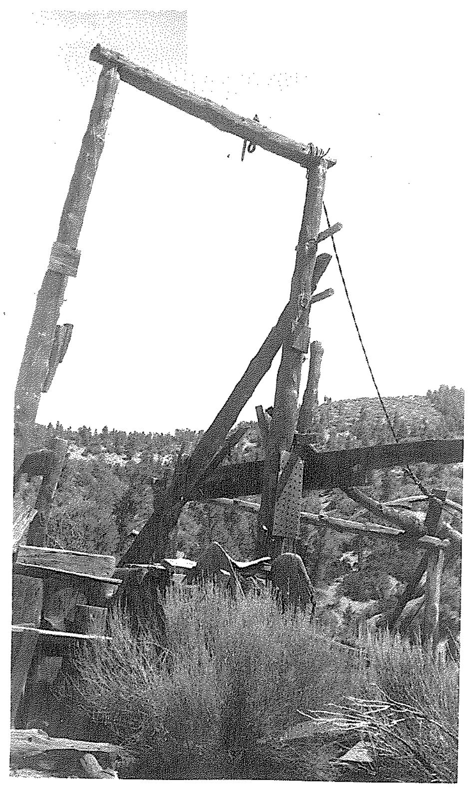

Fig. 19 An old shaft of one of the many borax prospects.

ductive beds. H.S. Gale in his describtion of the region describes the colemanite as being formed as a replacement of the limestone. However, boric acid is weaker than carbonic, so the reaction would have a tendency to work in reverse; but this might be taken into account by the greater volatility of the latter, which may allow for replacements when the limestone is treated with a hot concentrated solution of boric acid. W.F.Foshag has described colemanite as an alteration product of ulexite, which is one of the products of desiccation from saline lakes in volcanic regions.

There were three main mining outfits and many small prospects (Fig. 19). The three main companies were the Frazier, the Russell, and the Columbus (Fig. 20). Transportation was difficult, and was carried on at the start by twenty-mule teams. The borax was taken by these teams to Bakersfield in a trip of some seven days. Due to the finding of borax deposits much nearer railroads these mines were forced to close. However, in this period 35,000 tons of crude ore were removed at the approximate value of $1,000,000. The mines were reopened in 1911 but shut again in 1913. Due to the large deposits of kernite at Kramer, no colemanite deposits in Southern California will be mined until the former is exhausted.

Rotary Mud

Probably the most activity in the sphere of mining at the present time in this area is in the field of rotary mud. The materials in Lockwood Valley are on the whole very clayey, and just below the White conglomerate is a bed, 75 feet in thickness, of exceptionally pure clay. This is found just south of the Lockwood Valley road in the eastern part of the valley. This clay is mined from several large pits by steam shovels on to trucks (Fig. 21). The trucks carry the clay down to the ridge route at whose junction they have a pulverizing plant, where the clay is ground up. The property on which the clay is mined belongs to Don Cuddy, whose family was one of the region's first settlers.

Fig. 20 The mine dump of the old Stauffer Borax Mine (the Russell property) on Seymour Creek.

Fig. 21 The mining of rotary mud in Lockwood Valley.

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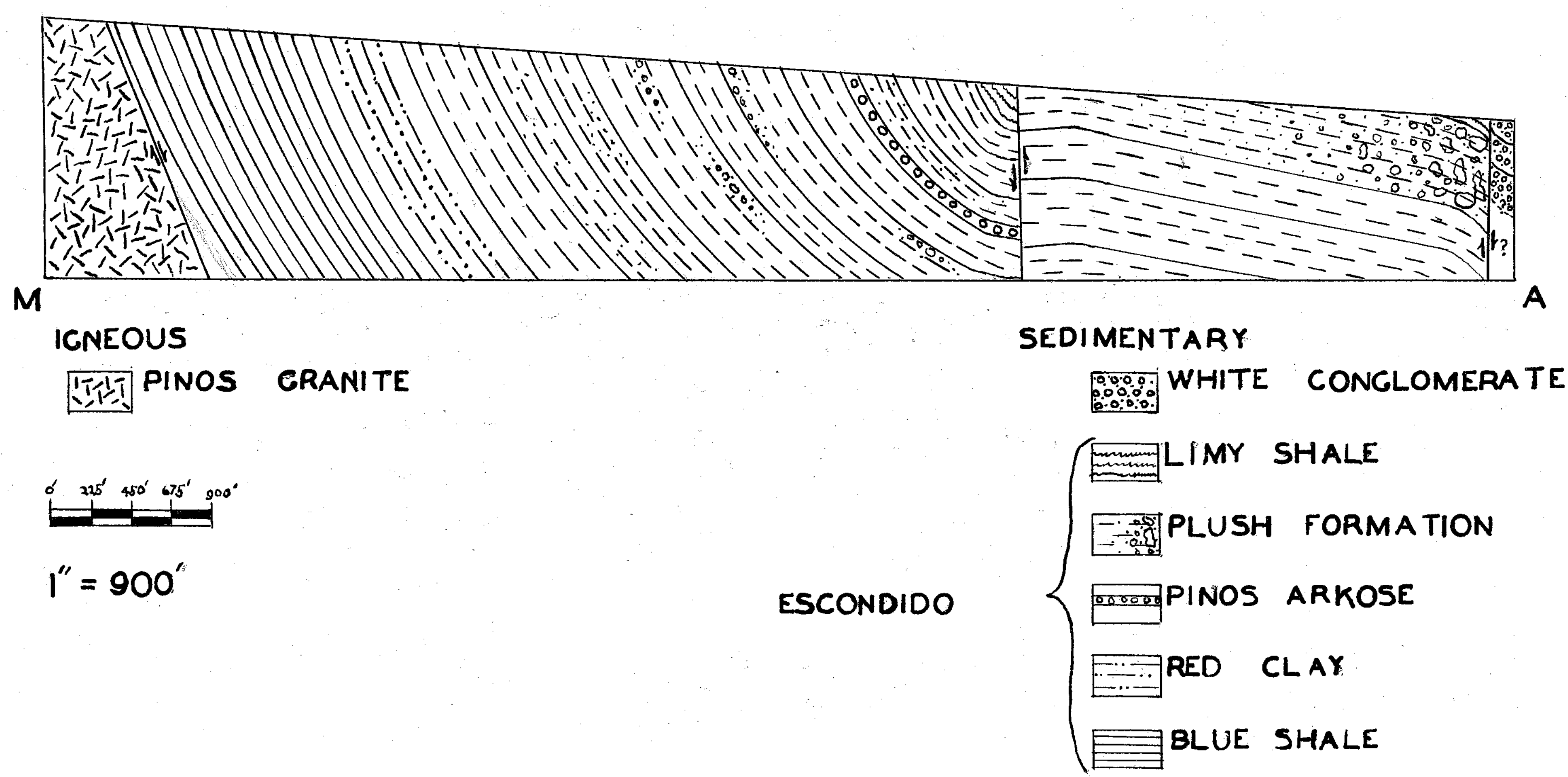
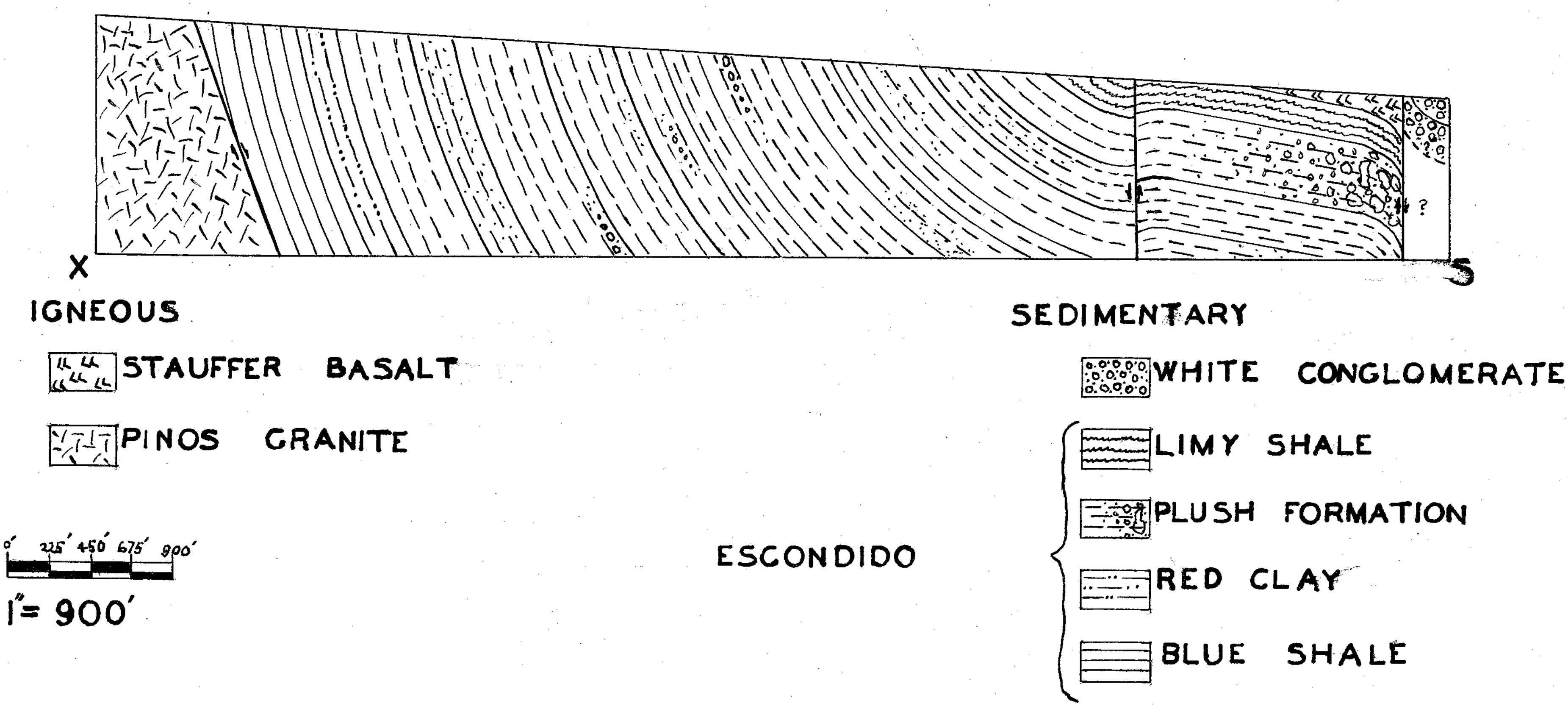
CROSS SECTION ALONG MIDDLE CREEK



CROSS SECTION ALONG BITTER CREEK



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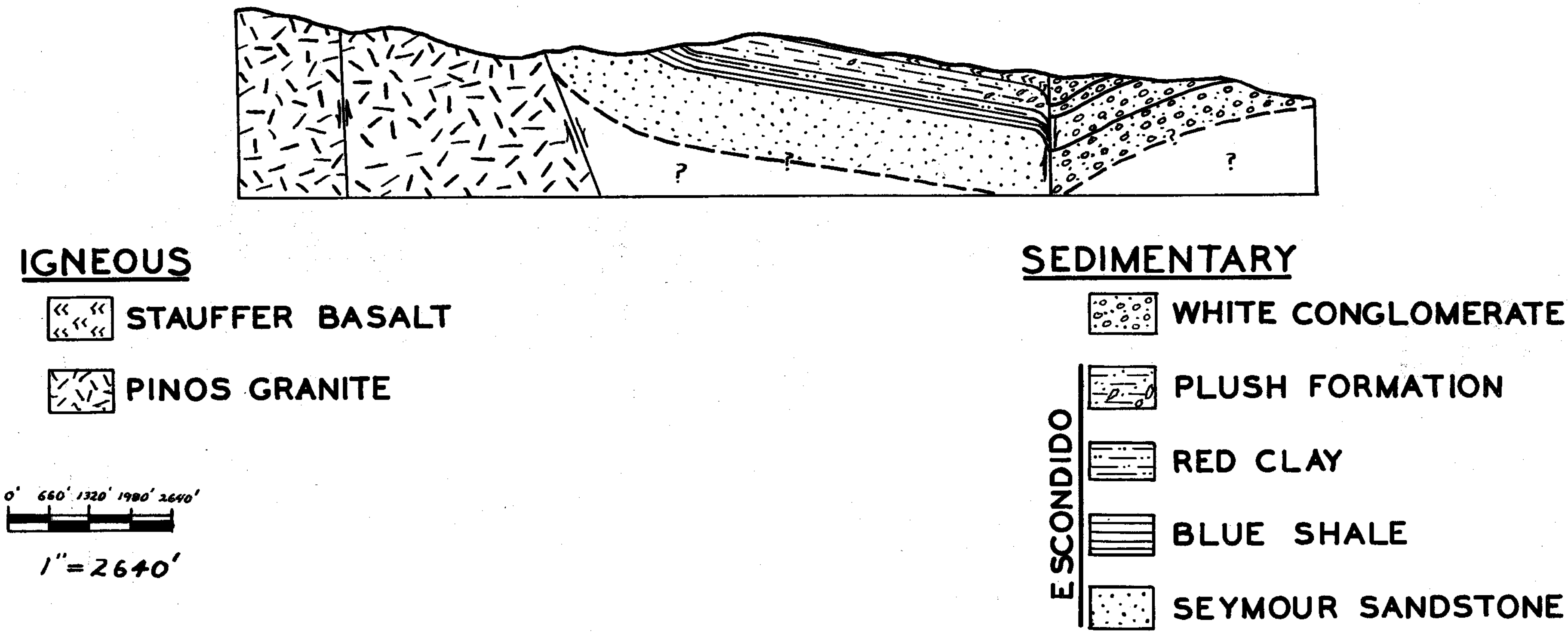
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IGNEOUS
STAUFFER BASALT
PINOS GRANITE
0' 660' 1320' 1980' 2640'
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SEDIMENTARY
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PLUSH FORMATION
RED CLAY
BLUE SHALE
SEYMOUR SANDSTONE