

Form 406

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FOREST SERVICE

GEOLOGY OF THE TEAKETTLE CREEK WATERSHEDS

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GEOLOGY OF TEAKETTLE CREEK WATERSHEDS

ABSTRACT

The Teakettle Creek Experimental Watersheds lie for the most part on quartzites of probable Triassic age. However one of the triplicate drainages has a considerable acreage developed on weathered granodiorite. Topography is relatively uniform and lends itself to triplicate watershed studies. Locations for dams are suitable if certain engineering precautions are taken. So far as observed botanic and soil conditions also lend themselves to experimental watershed studies.

INTRODUCTION

Location and Extent of the Area.

The Teakettle Creek Experimental Watersheds lie in Sections 15, 16, 17, 20, 21, 22, 27, and 28 of Township 11 South, Range 27 East, Mt. Diablo Meridian in Fresno County, California, and within the Dinky Creek District of the Sierra National Forest. These watersheds may be reached by automobile over two routes. Over the first and probably more direct route one proceeds from Fresno over the Kings River road via Piedra, Trimmer and Balch, a distance of about sixty miles. This had the advantage of passing through Trimmer near which is located Headquarters of the Kings River Watershed Studies and the big creek Experimental Watersheds.

The road is oiled as far as Trimmer and is fairly well kept up to Balch where the San Joaquin Power and Light Company maintains a permanent settlement for operation of their Balch Power House on the North Fork of the Kings River. About twelve miles above Balch and a mile off the main road to the Teakettle Creek Experimental Area is Black Rock Camp located near the intake for Balch Power House. This is a construction camp and is used as headquarters for the crew which is installing the equipment for the experimental watersheds at the time this report is written. The watersheds lie about ten miles above Black Rock Camp and comprise the upper portion of Teakettle Creek drainages.

The second route into Patterson Mountain is from Headquarters of the Sierra National Forest at North Fork. The road is oiled via Auberry, Pine Ridge, Shaver Lake as far as the Dinkey Creek Ranger Station. From that point fair dirt roads continue past McKinley Grove and Deer Meadows to Patterson Mountain. On the whole this route is better maintained during the summer season but is closed by snow earlier in the fall and remains closed later in the spring than the Kings River route. General location of the Experimental Watersheds and of the routes into them are shown on Figure 1, sketch map.

The Teakettle Creek Experimental Watersheds comprise all of the drainage of Teakettle Creek above the 6300 foot contour. There are three main branches and a number of smaller ones. The entire area consists of 2348 acres or about four square miles. The three main

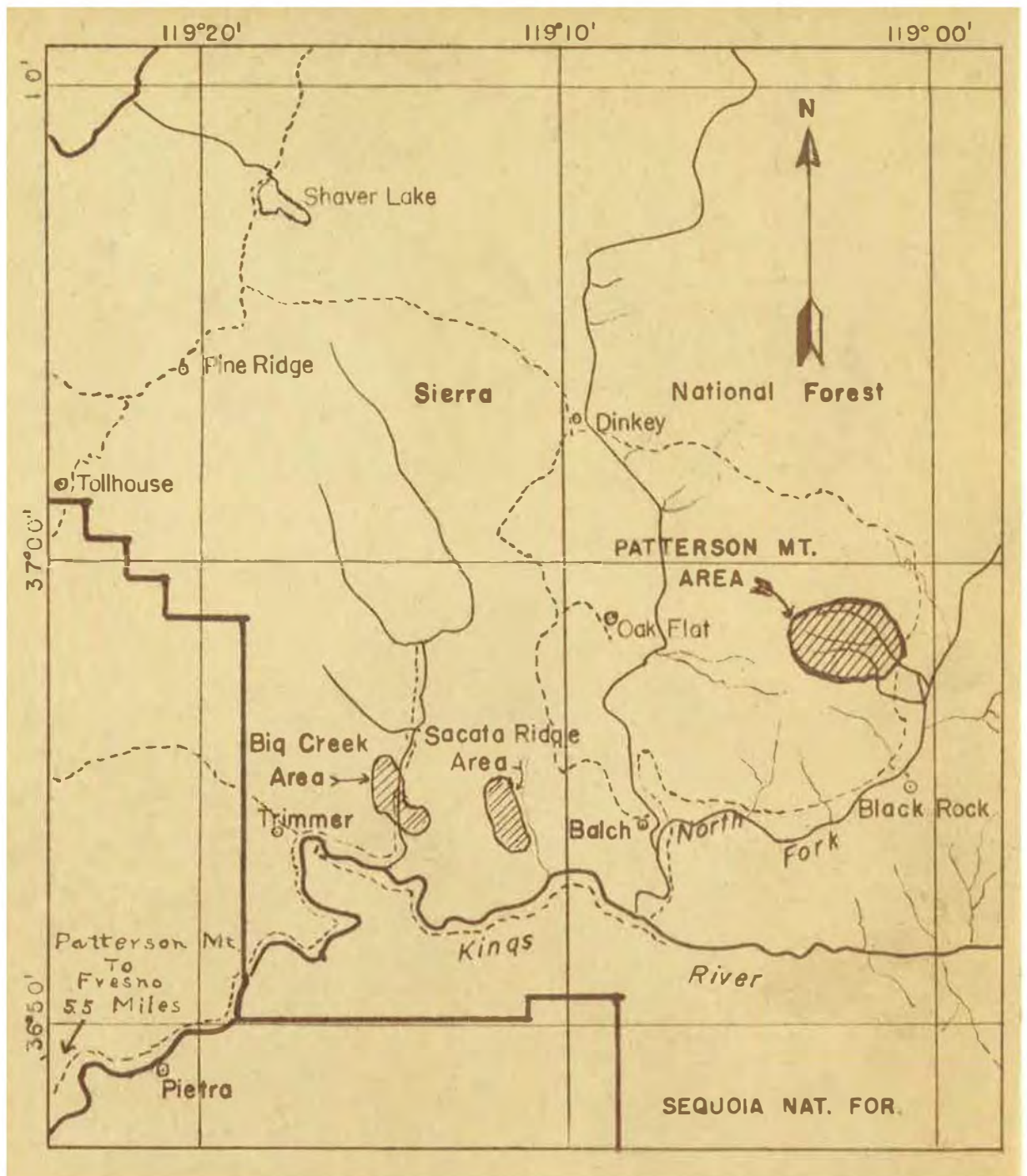


Figure 1 - Sketch map showing general location of the Patterson Mountain Watersheds, Kings River Branch, California Forest and Range Experiment Station, Fresno County, California.

branches of Teakettle Creek have been designated as drainages 1, 2 and 3; the south fork being drainage 1, the middle fork 2, and the north fork 3. The limits of these drainages together with the location of the dams is shown on the map of Areal Geology (back pocket). Table 1 shows the acreage of the three major drainages. Photographs illustrative of the Teakettle Creek watersheds conclude this report. Location of the stations from which they were taken is shown on map of photographs and samples in the pocket.

Table 1 - Area Table, Teakettle Creek Watersheds.

Drainage Number	I	Acreage
I	:	490
II	:	542
III	:	548
Smaller Units	:	768
Total	:	2348

Purpose and Scope of the Investigation.

The investigation was undertaken on verbal instructions from S. M. Munson, Associate Conservationist, as a part of the detailed studies relating to erosion and runoff of southern Sierra Nevada watersheds. This project is known as the "Kings River Watershed Studies" and is under general supervision of C. J. Kraebel, Senior Silviculturist, California Forest and Range Experiment Station. The geologic investigation is intended to include the following topics:

I - Determination of suitability of proposed damsites and to

provide geologic data for the selection of other sites

TABLE 2 – ACREAGE OF VARIOUS ROCK TYPES EXPOSED AT PATTERSON MOUNTAIN

WATERSHED	<i>Qm</i>		<i>Qf</i>		<i>Ql</i>		<i>Tb</i>		<i>Grd</i>		<i>Rl</i>		<i>Rq</i>		TOTAL ACRE- AGE	PER- CENT OF GRAND TOTAL
	ACRES	PER- CENT	ACRES	PER- CENT	ACRES	PER- CENT	ACRES	PER- CENT	ACRES	PER- CENT	ACRES	PER- CENT	ACRES	PER- CENT		
No. I	40.4	8					14.4	3	176.3	36	4.3	1	254.0	52	489.4	31
No. II	38.3	7			7.3	1	51.9	10	1.1	0.2			440.2	82	538.8	34
No. III	50.7	9	0.6	0.1			6.2	1	26.9	5	1.2	0.2	466.1	85	551.7	35
TOTAL	129.4		0.6		7.3		72.5		204.3		5.5		1160.3		1579.9	
PERCENT OF GRAND TOTAL		8		0.04		0.5		5		13		0.3		73		100

Symbols

Qm – Wet Meadows ; sediments ore loose and unconsolidated.

Qf – Dry Meadows ; sediments loose and unconsolidated, contain more gravel than *Qm*.

Ql – Landslide deposits containing much basalt.

Tb – Olivine basalt.

Grd – Granodiorite.

Rl – Limestone lenses.

Rq – Metamorphics, consist principally of quartzite with some schist.

in the future if needed.

2 - Geologic mapping of the experimental watersheds and preparation of geologic structure sections.

3 - Investigation of rock types as related to soil types.

4 - Investigation of ground water conditions as related to the geology of the area.

5 - Investigation of physiographic conditions.

Acknowledgements.

Dr. Cordell Durrell., Department of Geology, University of California, has kindly reviewed the general conclusions reached in this paper as related to the more general geologic problems of the southern Sierra Nevada and has made valuable suggestions regarding the petrography of Patterson Mountain rocks. Appreciation is extended to both superiors and colleagues of the California Forest and Range Experiment Station, Berkeley, California, for criticism of manuscript and assistance in the field. P. B. Rowe, Associate Silviculturist, has contributed a short report on various soil samples taken at Teakettle Creek which appears under its proper title below. Final preparation of maps, structure sections and various drawings has been largely the work of Messrs. C. A. Royse, C. W. Hoover and E. H. Roderick, draftsmen.

STRATIGRAPHY

General Character and Age of Rocks

Table 2 shows in summary the general nature and acreage of the different kinds of rock exposed in the Teakettle Creek Experimental Watersheds, and a general classification of them is given in Table 3. The Geologic map in pocket shows their surface distribution.

Table 3 - Classification of the Teakettle Creek Rocks.

Surficial Rocks:

Sedimentary Deposits.

Wet meadow deposits consist of loose, coarsely stratified lenses of silt, sand and gravel, occur along stream channels and are derived from erosion of underlying bedrock high in organic content.

Dry meadow deposits consist of loose, poorly stratified lenses of gravel, sand and minor amount of silt; occur for the most part in the lower valleys of the area and are derived largely from erosion of the granitoid portion of the watershed. These meadows are more porous than the wet meadows, are lower in organic content and contain very little clay.

Landslide deposits occur along the mid-course of Drainage 2. A hillside underlain by quartzite and capped by basalt has slumped. The deposits are a heterogeneous assemblage of the two rock types. They are gravelly, very porous and low in organic content.

Volcanic flows.

Olivine basalt flows cap a number of the ridges forming the boundaries of Drainages 1 and 2. The rock is dense and dark, contains abundant phenocrysts about 1 mm. in diameter of olivine. It breaks up into rough, angular blocks about the size of paving bricks, due to jointing and is extremely hard. It gives rise to shallow red soil and, due to its jointing, does not hold much ground water. It supports a slightly more xeric vegetation than most of the ridges, being characterized by fairly extensive stands of chinquapin and buck brush.

Basement Rocks.

Intrusive igneous rocks consisting of course-grained granodiorite underlie the eastern one-third of the watersheds. Aplite of the same parent magma occur in the remainder of the area as fine grained sills and stocks that intrude the metamorphic series. While the aplite is hard and does not disintegrate readily, the main body of granodiorite characterizing lower portions of the watersheds is decomposed to considerable depths which gives rise to loose, sandy soil deficient in colloidal content, and interspersed with large, irregular or rounded residual boulders. Where streams have oversteepened slopes, the granodiorite shows domes and spalling forms.

Metamorphic rocks which have been derived from former sediments and lavas underly the greater part of the Teakettle Creek Watersheds. The Metamorphic Series is predominately quartzitic but there are also lenses of impure limestone which have been mapped separately and belts of amphibolite-schists which represent former lavas and associated tuffs. There are minor lenses of biotite-schist which represent more argillaceous beds of the ancient series of deposits. The Metamorphic Series gives rise to a soil that is comparatively high in colloidal content and which supports good vegetation. Bold outcrops are not abundant and soils, while not as deep as in the granodioritic areas, cover the area much more uniformly.

In general the Surficial Rocks are all very much younger than Basement Rocks. The various Meadow Deposits and the Landslide are of Quaternary age while the Olivine-Basalt is presumably of late-Tertiary (Upper Miocene) time. The Granodiorite intrudes the Metamorphic Series and is hence the younger of the two kinds of Basement Rock. It is thought to be the age equivalent of the wide-spread granodioritic batholith which invaded much of the Sierra Nevada region in Middle Mesozoic (Late Jurassic) time. The Metamorphic Series is the oldest rock in the area and is definitely pre-granodioritic in age. It may be the time equivalent of Triassic rocks which are exposed in the vicinity of Mineral King or it may represent an older series known as the Calaveras Formation which has been shown to be Late Paleozoic (Carboniferous) in age and which is exposed in the vicinity of El Portal in the Yosemite region to the north-west. In accordance with usual geologic practice the oldest rocks will be discussed first, reserving the details of the youngest formation to the last.

The petrologic collection upon which the present study is based is deposited in the rock collections of the California Forest and Range

Experiment Station, Berkeley, California. The locations of the rock specimens from Patterson Mountain are shown on the map (see pocket in back) of photograph and sample localities.

The Metamorphic Series.

The metamorphic series represents an ancient group of rocks which accumulated in a basin of deposition that covered much of the region which is now the Sierra Nevada. The rocks are dominantly quartzitic and show under the petrographic microscope that they once consisted of sands of rather uniform grain about 1 to 2 mm. in diameter. These sands have since been cemented by silica and, when the rock is broken by the hammer, cement and former quartz sand grain alike are fractured. The quartzite is usually pinkish in color as the result of fine inclusions of an oxide of iron. More pure varieties may be white or light gray. Interspersed in the quartzite there are bands ranging up to several meters in thickness of fine-grained biotite-schist. In these the bedding planes of the formerly shaley sediments are clearly visible and lie parallel to planes of schistosity. Although the rocks have been thoroughly metamorphosed since they were deposited there does not appear to have been a high degree of folding. There is a rather uniform strike to the beds of about north thirty degrees east and the dips are for the most part within ten degrees of vertical. In the vicinity of the contact with the main body of granodiorite, dips and strikes become more erratic and

tend to conform with the dip and strike of the contact.

Of somewhat local occurrence are thin beds of impure limestone. These beds do not exceed fifty feet in thickness and are composed now for the most part of calcium silicate mineral which have resulted from the metamorphism that the rocks have undergone. As there is little carbonate present, the rocks do not tend to become cavernous and they do not present any problem of water leakage in the hydrographic basins in which they are found. The limestone lenses probably represent organic deposits which formed in the ancient basin of deposition in which they were layed down. Although they were examined carefully they did not yield any evidence of fossils. Metamorphism has been too intense and the former organisms which more than probably gave rise to the limestone have been completely obliterated.

Another line of evidence bearing on the marine origin of the metamorphic rocks is the occurrence of occasional bands of chert. In the older rocks of the Sierra Nevada cherts that haven't been intensely metamorphosed show that they are composed of the tests of Radiolaria - microscopic marine organisms that secrete a siliceous cover.

Included in the Metamorphic Series are beds of amphibolite-schist that at times aggregate a hundred or more feet in thickness. These rocks are customarily interpreted by geologists as being the metamorphic equivalents of basic volcanic flows and their associated tuffs. Amphibolite-schists are perhaps rather more common in the Triassic rocks of the Sierra Nevada although they may also occur in the older Paleozoic series.

Although there must always be doubt as to exact correlation of metamorphic rocks in this region unless there is paleontologic evidence in support, the rocks of the Metamorphic Series at Patterson Mountain appear lithologically similar to those of the Mineral King area described by Knopf (1929) and which Durrell (1936) has recently shown to be Triassic on the basis of fossils. The Patterson Mountain Metamorphic Series appears to differ from the metamorphic rocks of the Big Creek area on the lower Kings River which LaMotte (1936) tentatively correlated with the Paleozoic Calaveras Formation in that they contain less limestone, less amphibolite-schist, more quartzite and less biotite-schist. Durrell (personal communication, 1936) has expressed the opinion that the Patterson Mountain Metamorphics appear to resemble the Triassic rocks with which he is familiar more closely than the older Calaveras metamorphics.

Durrell (1936) in a recent report on the rocks of the Kaweah River basin reports a series of metamorphic rocks which he named as follows: There is an older Woodlake series consisting of metamorphosed "basic volcanic rocks, both flows and tuffs, bedded cherts of the radiolarian type, acid volcanic rocks, argillaceous sediments and limestone named in order of their abundance. Intrusions of diorite gabbro and serpentine are confined exclusively to the Woodlake series." This series corresponds exactly to the situation found at the Big Creek Experimental watersheds and there is little doubt that the Big Creek metamorphic series is the equivalent of the Woodlake series of Durrell. Three younger formations lie conformably upon the Woodlake in the Kaweah River basin and are named the Lemon Cove Schist, the Homer Quart-

zite and the Three Rivers Schist. These formations comprise the restricted Kaweah Series as that term is here used and are the rocks which Durrell found in the eastern part of his section. They lie upon the Woodlake series with apparent conformity. Durrell (personal communication, 1937) has stated that there is no valid reason for believing that the Woodlake and Kaweah series are closely related in time in spite of their apparent conformity. It appears from the writer's review of all the evidence that the Big Creek metamorphics best correlate to the Woodlake Series of Durrell and the Carboniferous Calaveras Formation further north. On the other hand the Kaweah Series (restricted) appear to be continued northward into the southern extension of the Patterson Mountain Metamorphic Series and it, in turn seems closest in point of lithology to the Mariposa and Amador formations of the Sonora Quadrangle, which are Mesozoic (probably Triassic). Both the Patterson Mountain Series and the Kaweah Series (restricted) are lithologically similar to the Triassic rocks of the Mineral King Region and are to be tentatively correlated with them and with the Triassic rocks of the Sonora Quadrangle.

Photographs showing areas of metamorphic rocks in the experimental area are numbered L-122, 123, 125, 129, 130 and 131.

The Granodiorite

Igneous plutonic bodies best described as granodiorite intruded the Metamorphic Series as aplite dikes and stocks and, in the eastern portion of the Patterson Mountain watersheds, a body of batholithic

proportion lies in fault contact with the older rocks. This mass is continuous from Balch at the junction of the north fork of the Kings River and Dinkey Creeks to the higher country at the headwaters of the Kings River. There is little if any doubt that it is to be correlated with the widespread series of batholithic intrusions which were injected into the earlier strata in the Sierra Nevada region in late Jurassic time.

Two phases of the granodiorite are developed in the Patterson Mountain area, a coarse-grained, deep-seated phase and a fine-grained, aplitic one. In the eastern one-third of the mapped area the granodiorite is of the coarse type. It consists of a light grey, coarse-crystalline rock composed of plagioclase feldspar, hornblende, minor amount of quartz and various accessory minerals. There are few dikes although local occurrences of both feldspar pegmatites and quartz aplites are noted. Jointing in the granodiorite is massive and wide-spaced. This condition results in weathering by a spalling off of the surface and gives rise to domes and rounded granite monoliths that are characteristic of the Sierran landscape. Where topography is comparatively flat weathering proceeds to considerable depths and surface rocks decompose in place. This gives rise to coarse, arkosic soil that is highly porous. The various mineral grains of the rock fall apart and the mass disintegrates into a granite grush, sometimes to depths of twenty feet or more. The soils that form on granite are therefore sandy and have high porosity. As the grains are relatively large granite soils do not hold their ground waters in storage for long periods

but allow them to migrate down hill toward the stream channels where the water reappears as springs.

In the area which is dominantly underlain by metamorphic rocks there are numerous occurrences of granite-aplite. Here the metamorphic rocks have been invaded from below by stocks and off-shoots dikes from the underlying batholith. For the most part these granitoid bodies have no great thickness and hence cooled rapidly after their injection into the older rocks. This has resulted in a fine-grained, although holocrystalline texture. They are all slightly more acidic in composition than the deepseated, coarse -grained phase of the eastern area as is to be expected. They contain more quartz and less hornblende than their coarser equivalents and are much more resistant to erosion for the various mineral grains are much more closely coherent. They behave quite similarly with regard to erosion to the quartzites into which they are intruded. If anything they are slightly more resistant. They do not have any detectable system of joints and hence form good locations for dams and hydrographic controls where they cross drainages. Their surface outcrop area is so small in comparison to the size of the Experimental Watersheds that they cannot be said to give rise to any peculiar soils type. Photographs L-135 to 157 illustrate the topography of granodiorite areas.

Olivine Basalt.

The next younger group of rocks in point of age that outcrop in the Patterson Mountain Experimental Watersheds are a series of Lava flows composed of dense, dark basalt containing numerous phenocrysts of olivine. They consist of two distinct flows, one upon the other. Their composition is alike and there is no reason to believe that there is any great time break between their extrusion. It is not possible to date them absolutely although there are several good lines of evidence that give an approximate idea as to when they were poured out. The structure sections clearly bring out the fact that the various isolated areas of basalt were once continuous with each other and that they have been separated by the processes of erosion, through downcutting from streams. There is no evidence on the area of any vent and it seems clear that the lavas have come from some distance. Elsewhere in the Sierra and especially in the Minarettas Country there have been flows of olivine basalt. They originated from vents located near the main crest of the mountains, and occurred at two different periods. The earlier flows are thought to have been extruded in upper Miocene time and the later ones during the late Pliocene (Erwin, 1934). The Patterson Mountain basalts should almost certainly be correlated with one or other of these periods of vulcanism. The relation of the flows to the present topography indicate that they were extruded upon a relatively gentle topography and flowed down a broad, mature valley from their source. Their bottom contact now slopes from west to east which is almost certainly not the way it sloped at the time of the extru-

sion. It is to be noted that basalt does not occur on the area of ~~granodiorite~~ but that two areas of basalt are cut off on their eastern end by the line of the metamorphic-granodiorite contact. This will be shown later to be a fault contact and that the metamorphic blocks is the down-throw block while the granodiorite is upthrown. Hence the basalt is older than the period of faulting. It is most probable that faulting occurred during the uplift of the Sierra Nevada block which took place for the most part during early and middle Pliocene time. Therefore it is concluded that the Patterson Mountain basalt flows are to be correlated with the earlier of the two periods of vulcanism which gave rise to basaltic flows in the Minarettes region and that they are of probable upper Miocene age.

The structure of the basalt flows is such as to give rise to an extremely porous rock which absorbs but does not retain ground water. Surface waters enter the rock through many small joints and pass rapidly to the base of the flows and along the bottom contact to the canyon sides. The upper surface of the flows dries out quickly and vegetation that grows upon them is slightly more xeric than that which occupies analogous ridges formed of schists and quartzites. As an instance of this may be cited the dense brush areas composed of chinquapin and manzanita which occur on the basaltic crest between drainages 2 and 3. Basalt breaks down to give a reddish soil that is comparatively fertile. This compensates somewhat for the reduced moisture of these areas and conifers of the region seem to grow nearly as well on basalt as upon areas of metamorphic rocks. Photographs L-114 to L-120 and 162 to 165 illustrate outcrops of basalt,

Wet Meadows.

It should be stated at the outset that it is not possible to give the relative ages of the various Quarternary meadow and landslide deposits. They are probably all more or less contemporaneous. They are differentiated on the map because of their different lithology and hydrographic characteristics and not because of any great difference in relative age. As wet meadows in aggregate cover considerable area they are discussed first. The presence of wet meadows on Teakettle Creek Experimental Area is conditioned not only upon erosion of upland and deposition by streams of fluctuating intensity. They are as much products of the biotic assemblage that exists in the region. Sheet-wash, soil creep and frost action; slumping, landslide and avalanch all carry surficial material from the side slopes into the stream channel. Snowfall breaks branches from trees and decay and wind cause them to fall and partially block watercourses. This results in the formation of many temporary dams behind which accumulate coarser and finer particles that are carried by freshets. Although temporary dams formed by fallen trees and branches decay rapidly they are replaced by others and meadows grow behind them. At times freshets act upon a rotted and weakened dam and carry it out and a small gully eats headward through a meadow and washes it away. The preservation, protection and replacement from time to time of natural debris dams in the stream courses is the key to control of erosion in mountain meadows. Parking, landscaping, clearing out of fallen timber along watercourses, is the first step toward promoting erosion in these places because it weakens the natural succession of control dams which nature provides. The second and perhaps more fatal step which man has frequently taken to promote erosion of mountain meadows

meadows is to attack the surface of the meadows through excessive and untimely grazing of stock. Without a protective mantle of both living grasses and sedges and decaying vegetable matter the spongy and absorptive meadows are converted into a light, powdery mass of silt and sand which is readily removed by spring freshets and the meadow which has taken perhaps a thousand or more years to form is converted into a system of gullies. While the timber resources of Patterson Mountain are of considerable value to Fresno County and their worth cannot be minimized, it is believed that the mountain meadows, particularly the wet meadows, form more important resources, for it is upon them, and others like them in mountain watersheds that the county must depend for its permanent year round supply of water both for agriculture and for hydro-electric power.

At the time of writing this report the mountain meadows of the Teakettle Creek Experimental area are in good condition. There is little evidence of gullying and that which has been noted appears to represent only the natural state which results from weakening and failure of natural dams from rot. There appear to be sufficient windfalls in the area to maintain the meadows in essentially their present state if the area is undisturbed.

Areally the wet meadows of the Experimental Watersheds make up a considerable part of the total acreage. It is also noted that they seem to be fairly uniformly distributed. Drainage 1 has 8 per cent wet meadowland, drainage 2 has 7 per cent, while drainage 3 has a total of 9 per cent. From the point of view of triplicate watershed studies the

meadows of these three drainages are as closely similar as could be desired. It is noted that wet meadows are not confined to metamorphic areas. In the writer's travels over the roads of the Sierra National Forest in pine and fir areas it has been his impression that their development is less extensive in areas of granite and granodiorite. If further study should show this to be the case, stricter conservation policy should be made for the smaller but more valuable watersheds which are underlain by metamorphic rocks. A suggestive occurrence of valuable timber located on metamorphic rocks is the McKinley Grove of Sequoia gigantea. Dr. Francois E. Matthes, U. S. Geological Survey (personal communication, 1937) has recently completed a detailed investigation of the geologic occurrence of this tree and has prepared a complete discussion of its geologic relationships which he intends to submit for publication in "Madrono". He informs me that Sequoia gigantea is found growing on all types of rock-metamorphics, granites and volcanics. Also of interest is the fact that it is largely restricted to unglaciated country. Where found on glaciated areas it occurs on moraines which weather to deep and rich soils. It is almost wholly but not entirely excluded from areas subjected to the most recent epoch of glaciation. In the north part of its range the tree is most frequently met with on areas of metamorphic rocks and in its southern distribution it is largely confined to areas of granitic substratum.

Photographs showing wet meadows are numbered L-121, 124, 126-128, 159-161.

Dry Meadows.

Certain meadows in lower portions of the Teakettle Creek Watersheds have been differentiated on the map because they do not have the same hydraulic characteristics as wet meadows. They are formed for the most part of coarser material and consist principally of sands and gravels with only minor amounts of silt. Also they do not appear to owe their origin to the processes of stream damming that have given rise to wet meadows. They occupy low, relatively flat areas below more elevated portions of the terrain and appear to be natural accretions of talus and sediment washed from higher ridges by stream freshets. They are all developed upon areas of granodiorite and this circumstance does not appear to be due to chance. It is thought that meadows of the wet type would have formed where dry ones now are, were it not for the porous nature of the underl in decomposed granodiorite which forms an aquifer to carry away ground waters which seep into the dry meadows from streams and melting snow banks in the spring. The presence of dry meadows has been noted by the writer in the area lying between Shaver Lake and Patterson Mountain along the Dinkey Creek road but only in areas of granodiorite. These areas rather uniformly support fine stands of timber but do not appear to represent potentially valuable storage for maintaining a regular and uniform flow in the streams. Occasionally one encounters small wet meadows that have formed upon dry ones. It is believed that they result from a gradual silting up process of dry ones from fine material brought in from ridges. This serves to create little local basins

that are sufficiently impervious to retain and store water. Thus a dry meadow gradually assumes the character of a wet one through temporary damming of streams by falling timber and by silting up.

That portion of the Experimental Watersheds which lie east of Drainage 3 and north of Teakettle Creek and which forms the flat on which dry meadows lie together with its surrounding ridges has somewhat the appearance of an ancient glacial cirque. The summit region of Patterson Mountain and the headwaters of Drainages 1 to 3 do not show any signs at all of ever having been glaciated. Fresh and conclusive glacial land forms are abundant in the granite gorge of the north fork of the Kings River which lies below and to the east of the experimental area. The granite gorge has evidently been carved to its present depth by either the latest Wisconsin stage of glaciers which formed the principal features of Yosemite Valley or else by the El Portal stage which preceded it. It seems clear that while Wisconsin and El Portal ice occupied the granite gorge of the Kings River, Patterson Mountain stood above it and remained unglaciated. However glacialogists recognize two earlier and more extensive advances of the ice during the Pleistocene. There are many subdued and modified glacial land forms over the whole of the upper Dinkey Creek basin and in the vicinity of Huntington and Shaver Lake. These are probably the result of the Sherwin stage which was the most extensive in this portion of the Sierra Nevada. It is quite possible that the area upon which the dry meadows are formed is the highly modified remains of an old cirque of the Sherwin

stage and that some of the sediment that goes to make up the present meadows is glacial debris that was left by the old Patterson Mountain glacierette when it melted away. This hypothesis would account well for the origin of the flats and also for the oversteep slopes that occur in the drainages lying to the East and north of Drainage 3.

Landslide Deposits.

Slumping and landsliding is rarely encountered on the Patterson Mountain Experimental Area. Several minor occurrences were noted but only one of sufficient magnitude to justify inclusion on the geologic map. This area occurs in Drainage 2 about one-third mile above the proposed dam site and on the north-facing slope. An area of about 7.3 acres has been involved to a depth of about 25 feet or possibly more. It consists of a heterogeneous mass of debris from basement quartzite and olivine-basalt which caps the ridge. While the canyon wall is fairly steep at this point it is no more so than at numerous other localities and there is no good explanation why landsliding should have occurred. That it did is shown by the nature of the rocks themselves, by topography which shows characteristic hummocks on the slide and a fairly well preserved pull-away scarp, and finally by the fact that many of the older trees lean down hill at the base and gradually curve until their tops have assumed the vertical attitude. This shows that sliding has occurred within the life of many of the living trees and may continue intermittently from time to time as the stream which is

cutting away the toe of the slide removes its support. The date at which sliding first became active may have been prior to movement which causes the trees to lean but it probably occurred within the last five hundred years. There is no possibility of saying when sliding will occur again or for that matter that it ever will become active during the life of the experiments proposed for the area. Also it is quite possible that landslides may develop at other points in the watershed. However this eventuality is not thought to be probable during the relatively short span of a few human generations.

THE SOILS.

During the latter part of October, 1936, the writer was accompanied by P. B. Rowe, Associate Conservationist, on a short trip to the Teakettle Creek watersheds for the purpose of examining soils. Mr. Rowe's report is appended below. The soil samples that were taken are shown on the location map of photographs and samples in green symbols. Soil samples S-1 to S-4 were taken earlier in the season but Mr. Rowe has not found it desirable to consider them. Samples S-5 and S-6 are from metamorphic rock types and S-7 is granoidioritic. The soil analyses impress the writer with the fact that there is a considerable difference between those derived from igneous intrusive rocks and those derived from metamorphics. The schist soils are more cohesive, less porous, have a higher percentage of colloid and do not appear to erode as readily as do the granitoid soils.

RS
1-2
Watercycle and Soil Studies
Patterson Mountain

March 30, 1937

MEMORANDUM FOR R. S. LANDTE

Following are the results of the analysis of the soil samples collected October 22nd from the Teakettle Creek triplicate watersheds:

Site No. 1: Above Dam #2, 25% slope, northeast exposure.

Forest Cover: Open fir, 150 to 200 years.

Forest Floor:

L, 1/8 to 1/4 inch, undecomposed fir needles.

F, 3/4 to 1 inch, partially decomposed matted fir needles.

H, 1/8 to 1/4 inch decomposed, matted organic matter containing mold and fungus (mycelium).

Soil: A1, 0 to 1/2 inch grayish black, sandy loam, loose porous mull. (Sample #1)

A2, 1/8 to 6 inches grayish brown, sandy loam crumbly. (Sample #2)

B, Not visible.

Site No. 2: 1/4 mile above proposed location for Dam #3, 50% slope, southeast exposure.

Forest Cover: Open over-mature fir.

Forest Floor:

0 to 1 inch, undecomposed fir and pine needles.

Soil: A, 0 to 12 inches grayish to reddish sandy loam, very loose, crumbly porous structure. (samples #3 and #4).

B1, 12 to 30 inches reddish-brown sandy loam containing many small quartz particles, fairly compact in place, crumbly upon handling. (Sample #5).

B2, 30 to 50 inches red soil, compact, hard and lumpy when dry. (Sample #6).

This soil profile ranges from one foot in depth on the steep slopes to over ten feet at the bottom of the slopes. The C horizon contains many small gravel and rock particles breaking off sharply into the solid, hard and comparatively unweathered quartz-schist or quartzite parent rock.

Site No. 3: 1/4 mile below proposed location of Dam #3, 25% slope southeast exposure.

Forest Cover: Open ponderosa pine fir type, 150 to 200 years, understory of open brush, mostly vaccinium.

Forest Floor:

0 to 1/2 inch undecomposed pine and fir needles.

Soil: A1, 0 to 18 inches light gray, sandy loam, very crumbly, containing root hairs and a small amount of organic matter. (Sample #7).

B1, 18 to 30 inches, grayish-brown sandy loam, very crumbly porous structure, containing many root hairs, insect and animal burrows. (Sample #8).

B2, 30 to 60 inches grayish brown sandy loam, containing small particles of partially decomposed granodiorite, (Sample #9).

This is a residual soil overlaying a deeply weathered granodiorite rock formation; the upper C horizon ranging in depth from 3 to 12 feet, is composed of the weathered or decomposed parent material.

The following is a tabulation of the analysis made of these soils:

These data indicate that although the physical properties of these two soils types are somewhat similar there may be a considerable difference in their soil water relationships. The granodiorite soil contains more sand and less clay; has a lower moisture holding capacity; is less compact, and is somewhat lighter in weight than the Schist soil. Of the two it would be expected that the granite soil, other conditions being equal, would yield the greater amount of water-stream flow.

(Signed) P. B. Rowe
Associate Silviculturist

Comparison of Certain of the Physical Properties of Patterson Mountain Schist and Granodiorite Soils.

SOIL	SCHIST (S-5)			SCHIST (S-6)			GRANODIORITE (S-7)		
Sample No.	#1	#2	#3	#4	#5	#6	#7	#8	#9
Horizon	A1	A2	A1	A2	B1	B2	A	B1	B2
Depth in inches	0 - $\frac{1}{2}$	$\frac{1}{2}$ - 4	0 - 3	6 - 9	9 - 15	30	0 - 18	18 - 30	36
Mechanical analysis									
Fine gravel	.85	5.20	.11	1.59	2.77	1.29	1.59	2.68	2.45
Coarse sand	16.13	17.25	15.01	19.95	15.26	14.19	19.56	15.30	24.50
medium sand	21.52	16.12	23.55	21.25	21.41	25.30	21.95	21.35	20.77
fine sand	19.74	21.10	20.81	21.95	20.35	24.40	21.23	23.51	19.60
Very fine sand	9.58	10.10	9.87	7.31	13.60	7.07	11.45	15.86	15.67
Total sands	67.82	69.77	69.35	72.05	73.39	72.25	75.78	78.70	82.99
Silt	22.47	20.30	18.31	15.77	14.80	18.67	14.31	13.37	10.52
Clay	3.55	3.76	3.85	4.60	3.68	3.88	2.51	1.79	2.05
Coll. Clay	1.59	2.29	5.83	1.60	2.95	2.48	1.34	5.46	3.87
" " (.001-)	3.19	3.20	1.67	4.92	4.29	3.84	4.94	.03	.01
Loss on ignition	11.17	10.31	8.57	5.58	5.17	4.77	7.52	5.55	3.35
Total	109.79	109.63	107.58	104.52	104.28	105.89	106.40	104.90	102.79
Hydrogen ion conc.	5.61	5.83	6.81	6.82	6.87	6.66	5.63	5.93	5.76
Moisture equivalents	29.51	21.89	17.59	15.25	15.79	17.50	15.19	11.60	9.78
Volume wt., 0-2 in layers		.74			.93			.63	

GEOLOGIC STRUCTURE

Internal Structure Within the Metamorphics

The metamorphic series within the Patterson Mountain Area (see Geologic map and structure sections in pocket) has a fairly uniform structure. Dips for the most part are regularly within ten degrees of the vertical. Strikes likewise are quite uniformly about North 15 to 30 deg. East except where taken in the vicinity of the granodiorite contact or where modified by dikes. With vertical dips it is not possible to state which side of the section was originally the top when the beds were first layed down in the absence of fossil evidence. Also, due to the intense metamorphism which the series has undergone, it is not possible to state that the beds form one thick series which all dip the same way or whether they represent one or more isoclinal folds. The metamorphic series is probably more than 15,000 feet thick at its widest point when measured across the strike. This would seem to indicate that there are one or more isoclinal folds present and that there must be some repetition of beds. This could not be detected however, in the experimental area. The uniform development of quartzite over much of the series will make it difficult to unravel the internal structure of this sequence. The Kaweah series is estimated to be over 25,000 feet in thickness by Durrell (1936) and this is exclusive of the woodlake beds. It is quite possible that the Patterson Mountain Metamorphic series represents only a partial sequence of a formerly thicker series that were in extension of the Kaweah deposits.

External Relationships

The metamorphic series is probably for the most part in intrusive contact with the granodiorite. This simple relationship however does not hold for the area mapped except with regard to the smaller dike-like bodies. The main contact across the Teakettle Creek drainages has resulted from faulting. This is shown by several lines of evidence. Basalt lying upon the metamorphic series is cut off sharply at the contact at two separate localities and does not appear in the eastern granodiorite area. Fault gouge occurs all along the contact wherever it is possible to get at the rocks for observation. At several localities it was possible to observe the dip and strike of the fault plane. The presence of a fault of some magnitude seems abundantly demonstrated. The nature of movement has been as shown in the structure sections. It is not known how far north and south it extends. In the vicinity of Mc Kinley grove and again above Balch at the south end of the Patterson Mountain Metamorphic Roof pendant it seems equally clear that the contact is intrusive. There is little to be said as to how far below the surface the metamorphics extend before reaching the main contact with the granodiorite. There is not an abundance of dikes and offshoot bodies from the granodiorite in the metamorphics at the experimental area. This would seem to indicate that the main contact lies at considerable depth, possibly a thousand feet of overburden would have to be eroded to reach it.

One other structural feature remains for discussion. That is the present slope of the bottom contact of the basalt flows. It slopes uniformly from the crest of Patterson Mountain at about 8,000 feet eastward toward Number 2 damsite at the 6,900 foot level. The distance is about 8,500 feet. Thus the bottom contact dips eastward 671 feet per mile. Uniformly developed thickness of basalt flows of the character of the Patterson Mountain eruptives would not result from lavas travelling over such a steep surface. Also it has been brought out that these flows most probably emanated from vents along the main axis of the Sierra Nevada some 30 miles to the east. No matter how little the slope, they could not possibly have run up hill. It is most probable that the surface sloped about 50 to 100 feet per mile at the time the basalt was poured out and that the slope was to the west. Faulting in late Pliocene time when the Sierra reached their present elevation tilted the metamorphic block of Patterson Mountain slightly toward the east and depressed its margin some 750 to 800 feet. This gives some idea of the magnitude of the Patterson Mountain fault.

HISTORICAL GEOLOGY

In connection with the Teakettle Creek Experimental Area nothing is definitely known prior to the beginning of the Mesozoic Era. ~~Beginning~~ with Triassic time there was an extension of the sea which reached from Taylorville at the north along what is now the western front of the Sierra Nevada through Mariposa and extending across the

the range through The Patterson and Mineral King areas to the Inyo Mountains. Its southern limits were probably located in the Peninsular Range of San Diego County or extending into Baja California. There was a land mass lying to the east and there is some evidence pointing to the conclusion that another landmass lay to the west from the Klamath region southward along what is now coastal California. There is little evidence to show whether the long inland sea opened to the north or to the south. Sediments accumulated in this trough from adjacent landmasses and in the vicinity of Patterson Mountain they were predominately sands. Interbedded with them were minor quantities of muds and silts and also small lenses of limestone were layed down. It is reasonable to suppose that the limestone now found on the Experimental Area was once the accumulation of shells of marine, lime-secreting organisms. The remains of a few such animals have been found in the Mineral King area and again in other localities from the Santa Ana Mountains of Orange County to as far north as Taylorsville. Sufficient is known of this marine mollusean fauna to indicate that conditions of temperature of the sea water changed from time to time and that boreal migrants from the north replaced more southern forms of life. There are certain cherts in the Patterson Mountain Metamorphic series which suggest the radiolarian cherts of the Mariposa formation which were formed largely from the siliceous tests of microscopic

marine organisms that now inhabit warm marine waters. During the time these deposits were forming at the bottom of the Triassic seaway there was active vulcanism in the region. In the vicinity of Mariposa large quantities of lava of basaltic and andesitic composition were extruded upon the marine floor. Minor amounts of this type of lava also occur at Patterson Mountain interbedded with the dominant sands. This would indicate that Patterson Mountain was at some distance from the centers of eruption. In time the seaway appears to have completely filled with sediments brought to it from surrounding landmasses and Triassic time came to an end. In all Triassic time lasted about 30 millions of years and ended some 150 millions of years ago.

In the succeeding period of earth history, which is known as the Jurassic, little if anything seems to have happened during the first 30 million years or so. In the vicinity of Taylorsville the old Triassic seaway was still in existence and receiving sediments. But at Patterson Mountain the land was probably close to sealevel where little deposition went on. Possibly it was slightly elevated and undergoing a small amount of erosion. However during the last several million years or so of the Jurassic great things took place. There were great upwellings of molten rock from depth which were accompanied by wide-spread crustal movements. The

Triassic sandstones and shales were squeezed and thrown up into folds so that the formerly horizontal beds assumed a vertical attitude. As the molten material stopped its way upward it melted the bottom of the Triassic beds and subjected them to great heat and pressure. This resulted in changing their mineral composition from sandstones to quartzites; from silt and shale to biotite-schist; from limestone to marble and from volcanic lava flow to amphibolite-schist. At times upthrust of molten rock was so great that it was injected between layers of older Triassic rocks and today, after it has completely cooled, we find it on Patterson Mountain in the form of aplite dikes and stocks between layers of older quartzite and schist. The main mass of the upwelling molten rock, or magma as it is called, probably never reached the surface except in minor amount. For the most part it cooled in place beneath the Triassic overburden. Its contact with the Triassic is highly irregular and much of the older rock must have been melted and engulfed by the Jurassic magma. The latter, now that it is cooled and forms hard rock is known as granodiorite. The last few millions of years of Jurassic time saw profound changes in the face of the earth. It is known by some as the Sierra Nevada Revolution. At that time the Sierra were first elevated and they have remained above sea level ever since. Similar earth movements and upwellings of granitic magma took place around the entire rim of the Pacific ocean from Tierra del Fuego to Alaska

and down the coast of Asia to Australia and New Zealand. Granite batholiths of tremendous size were injected and mountain ranges upthrust. One of the largest of these batholiths is known as the British Columbia batholith and extends from the Cascades of Washington to Alaska, a total distance of 1,200 miles. The Sierra Nevada Batholith has recently been shown by Cloos (1933, 1937) and others to be a composite of many smaller bodies which were injected at about the same time but which are distinct from each other.

At the close of Jurassic time Patterson Mountain may have stood as high as it does today but it must be understood that the rock which forms its present summit was at that time buried beneath many thousands (At least 10,000) of feet of over-burden which have since been eroded away and that there have occurred several later uplifts.

The period following the Jurassic is called the Cretaceous. At Patterson Mountain the land was well above sea level at the start of the period and by the end of about 60 millions of years it had been brought down fairly close to sea level by processes of erosion. The material which was eroded from the summits of the ancestral Sierra Nevada is now found in an extensive series of sandstones and shales that lie along the western flank of the

Sierra and take their name from the town of Chico where they are well exposed. The Chico deposits are known from the northern Coast Ranges to the coastal plain of San Diego County and south into the coastal plain of Baja, California. At or near the end of Cretaceous time the Sierra were again elevated although probably not as greatly as they were during the Sierra Nevada revolution. During the initial epoch of the succeeding Tertiary Period, which is known as the Eocene, the climate in the Sierra was unlike that of today. This is known from the remains of plants which grew at that time and were buried in muds and silts which were carried by the Eocene rivers. These plants tell a story of semi-tropical conditions in the vicinity of Placerville and Grass Valley. Similar conditions must have prevailed at Patterson Mountain. There is little known of conditions which obtained during the Oligocene or second epoch of the Tertiary period. No doubt erosion of mountains continued. By Miocene time the mountains had been worn down to near sea level although the present crest must have stood from 1,500 to 2,000 feet high. Stream slopes of 100 feet to the mile prevailed. Vulcanism was again the order and lavas were poured out over the low hills which formed the crest at that time and flowed down the gentle stream channels westward toward the Great Valley. The remains of these flows are still to be seen along some of the ridges on the Patterson Mountain area and again in the Koweah River basin.

During the Pliocene epoch which brought the Tertiary Period to a close the Sierra Nevada were re-elevated once more and practically reached their present elevation. In fact elevation of the range probably still continues slowly but in general things were about as they are by the end of Pliocene time perhaps two million years ago.

The Pleistocene epoch or glacial age was initiated and a series of stages of refrigeration separated by warmer intervals ensued. It seems probable that the eastern part of the Experimental area was a breeding ground for ice during one of the early stages of refrigeration but this cannot be shown conclusively. At any rate the canyon of the North Fork of the Kings River below the Experimental Area carried a large valley glacier. This must have occurred at least two times and Patterson Mountain stood above the ice for the most part untouched. The North Kings glacier headed in the country in the vicinity of Hell-for-Sure pass and the Le Conte divide. Since Pleistocene time the ice has retreated to the higher crests of the Sierra and the present flora and fauna has come to live on Patterson Mountain. Within very recent years there has been an event which may have a considerable effect on its erosional history and help to speed it on its way to the ocean. I refer to man. He has entered the area. He has used it for grazing and he may log it.

Both these practices tend to increase the speed of the erosive processes which nature constantly employs to wear down all the lands which lie above the sea. Given enough time she can base-level a continent. Given enough Man she will not require as much time.

GEOMORPHOLOGY

The land forms of the Teakettle Creek Experimental Area are principally the result of normal erosion in a humid cycle. As the result of Miocene peneplanation the area was reduced at least to low relief as shown by the ancient basalt flow which crosses the area. In Pliocene time the area was uplifted and streams rejuvenated, in the normal cycle. The Miocene surface was trenched to a considerable degree. In the Pleistocene there were successive stages of refrigeration interspersed with others of the normal humid cycle. During one of the earlier stages of glaciation there appears to have been a breeding ground for ice in the north-east portion of the experimental area which gave rise to a small cirque. However the main portion of the area seems always to have remained free from the effects of ice. Glaciation of the North Fork of the Kings River to the east of the area caused the cutting of a deep Yosemite-like valley which left the headwaters of Teakettle Creek hanging many hundreds of feet above the master stream. Since the retreat of the last glacier in the Kings River, Teakettle Creek has notched its lip and is actively cutting back

into the old pre-glacial valley. The old cirque has become practically obliterated by normal processes and the area may be said to be in an early stage of youthful topography in the N / 5th cycle of normal erosion.

The three hydrographic basins selected for experimental purposes and below which damsites 1, 2 and 3 have been selected are topographically comparable and appear suitable so far as land form and size are concerned. This is well brought out in the three profiles of the stream channels as plotted from the base map and found in the back pocket. Main channels slope uniformly close to 12 percent and side streams average about 18 percent with only slight deviation from mean slopes between basins.,

PROPOSED DAMSITES

DAM # 1

This site is located at the extreme lower end of the Experimental Watersheds near the break between the old upland valley of Teakettle Creek and the Yosemite of the Kings River. The granodiorite is partially decomposed and it is thought that, if finally selected, this dam will require thorough water-proofing by means of gunnite. Although the south crest of the #1 basin is not high and the country rock partially decomposed there is no evidence that incipient piracy is taking any water out of #1 hydrographic basin. However with a dam in place this eventuality must be guarded against.

Dam #2

This site is located upon resistant quartzite. It is thought to be an excellent location for a dam so far as leakage and gunnitting operations are concerned. The defect in this location lies in the fact that there is an incipient case stream piracy 1,000 feet upstream which is causing leakage from hydrographic basin #2 into basin #3. The nature of this leakage is more fully discussed below. Damsite #2 is geologically suitable with the exception noted.

Dam #3

This site is located in the upper end of a dry meadow. More solid foundations could be found in solid quartzite a few rods upstream. If the advantage of a shorter haul outweigh the problem of digging to bedrock there will also have to be a considerable amount of gunnitting done to waterproof the reservoir. From the point of view of the geologist this damsite should be relocated slightly upstream where bedrock can be reached more readily.

The Pirate Stream

About 1,000 feet upstream from damsite #2 and on the divide between hydrographic basin #2 and #3 there is an unusual condition. Stream #2 runs in a channel about 7 feet below its bounding crest. On the #3 side of the crest and about 18 feet below the bed of #2 stream there is a spring which carries about 15% of the water in the channel of #2. This water is derived from leakage through the crest and represents a loss to #2 stream and a corresponding increase to the flow of #3 stream at #3 dam. If this condition were allowed to continue

indefinitely the entire headwaters of #2 would be diverted to #3. This of course would not occur during the life of the experiments which are proposed for the area. Nevertheless the leakage is very difficult to estimate accurately because of seepage through the crest which never reaches the surface until it arrives at the creek bed of #3. About 700 feet above the point of incipient stream piracy in basin #2 a thin aplite dike of granodioritic composition outcrops. This dike forms an excellent hydrographic control and it is suggested that if a small diverting dam were installed at that place that water arising in upper Hydrographic Basin #2 would be readily flumed past the point of piracy and all water restored to the lower channel of the proper stream. This appears preferable to the alternative of seeking damsites for both #2 and #3 drainages above the point of Piracy and the point of capture. Photographs illustrating the piracy are numbered L-106 to 113 and 166. Colored enlargements of L-112 and L-166 conclude the photographic report.

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TEAKETTLE CREEK WATERSHEDS



Panoramic view across Drainage 2 to crest leading to Drainage 3. The figure in center (Harold Isgrigg) stands at low point of divide where stream piracy may divert the headwaters of Drainage 2 through a short tributary stream into Drainage 3.

R. S. LaMotte L-106 to L-110 10/4/36



Figure (Harold Isgrigg) standing by small wet meadow in Drainage 3 immediately below divide leading to Drainage 2. The meadow results from seepage from Drainage 2 and indicates point at which stream piracy may occur thus diverting headwaters of Drainage 2 into basin of Drainage 3.

R. S. LaMotte L-111 10/4/36

TEAKETTLE CREEK WATERSHEDS



Figure (Harold Isgrigg) standing at spring in Drainage 3 which diverts part of runoff in Drainage 2 and introduces a case of incipient stream piracy above the proposed sites for dams. This stream represents probably 15% of the flow in Drainage 2.

R. S. LaMotte L-112

10/4/36



Details of flow from spring pirating part of Drainage 2 runoff to Drainage 3 taken below photo L-112.

R. S. LaMotte L-113

10/4/36

TEAKETTLE CREEK WATERSHEDS



Panorama of crest at headwaters of Drainage 1. The ridge is formed of two Tertiary basalt flows lying unconformably upon Quartzite and schist. The latter may be seen in the foreground.

R. S. LaMotte L-114 to L-116

10/4/36



Panorama in continuation of the one above showing the eroded surface developed upon Quartzite and schist near the headwater of Drainages 1 and 2. The clump of trees in middle distance are aspen (Populus tremuloides).

Other tree species are Pinus Murryana and Abies spp.

Shrubs are Castanopsis sempervirens and Ribes sp.

Elevation about 8,000 feet.

R. S. LaMotte L-117 to L-119

10/4/36

TEAKETTLE CREEK WATERSHEDS



Saddle at crest back of Drainage 2. At right middle distance tertiary basalt flows rest unconformably upon upturned and deeply eroded Quartzite and Schist. Tree species mostly Abies spp. with some Pinus murrayana.
R. S. LaMotte L-120 10/4/36



A wet meadow near headwaters of Drainage 2. Distance shows the even skyline characteristic of the Miocene peneplane broken by a group of Monadnocks (Mt. Reinstein, Finger Peak, etc.) in the far distance.
R. S. LaMotte L-121 10/4/36

TEAKETTLE CREEK WATERSHEDS



Summit of Patterson Mountain. The rock outcroppings are upturned and eroded Quartzites. Vegetation mostly Abies spp.

R. S. LaMotte L-122

10/4/36



Looking down Drainage 2 from summit of Patterson Mountain. Surface developed on upturned and eroded Quartzite and schist. Note the gentle slope characteristic of the summit areas which represent all that remains of the Miocene Peneplane.

R. S. LaMotte L-123

10/4/36

TRAKETTLE CREEK WATERSHEDS



Wet meadow developed on Quartzite and schist in valley
tributary to Drainage 3.

R. S. LaMotte L-124

10/4/36



Outcropping of quartzite in Drainage 3. Soil sample taken
at this point.

R. S. LaMotte L-125

10/4/36

TEAKETTLE CREEK WATERSHEDS



Looking up wet meadow on side branch of Drainage 3,
developed on Quartzite and schist. Soil samples
taken here.

R. S. LaMotte L-126 to L-128

10/4/36



At north crest of Drainage 3 looking north to show
remnants of the Miocene peneplane. Foreground on
Quartzite.

R. S. LaMotte L-129

10/4/36

TEAKETTLE CREEK WATERSHEDS



Panoramic at north crest of Drainage 3 looking east.
The remnants of the Miocene peneplane is well illustrated.

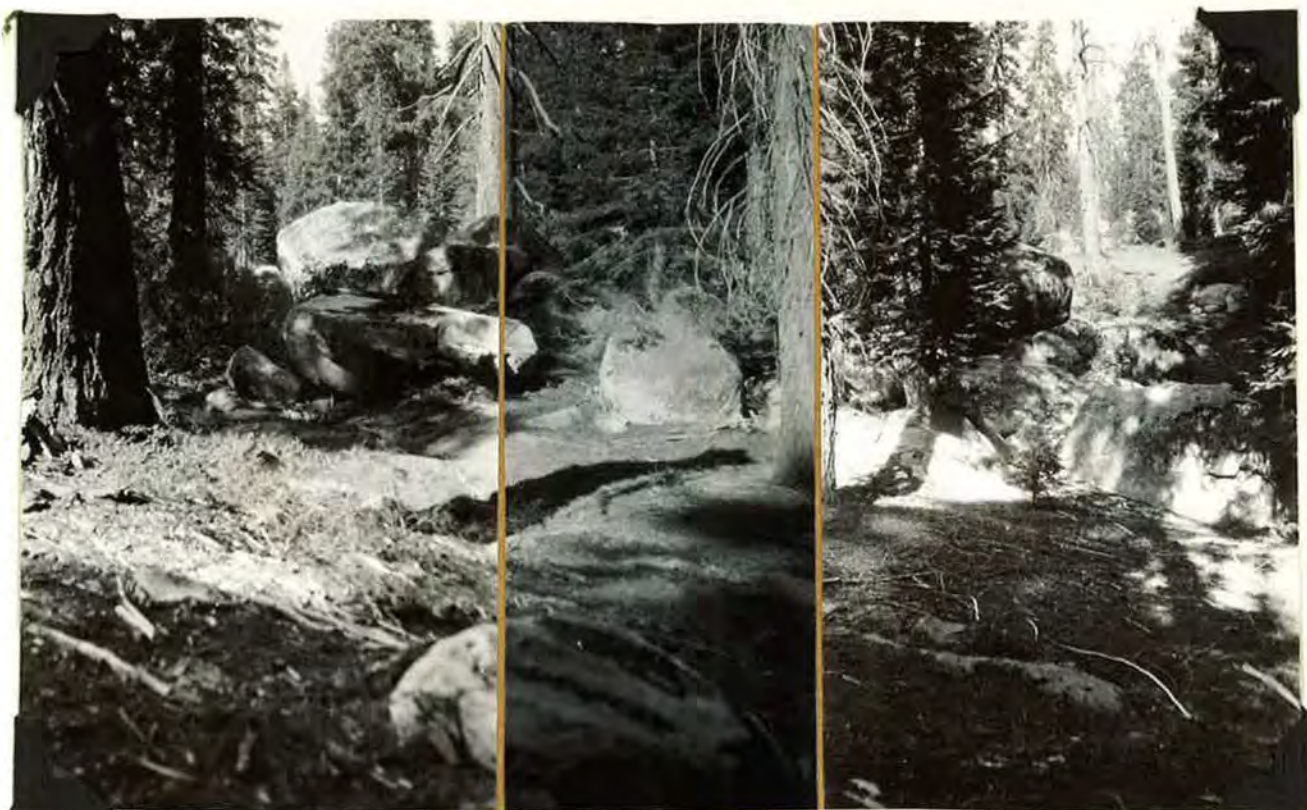
R. S. LaMotte L-130 to L-131 10/4/36



Drainage developed on Granodiorite in lower Patterson Mountain area. Not within proposed watersheds. A dry meadow.

R. S. LaMotte L-132 to L-134 10/4/36

TEAKETTLE CREEK WATERSHEDS



Lower Patterson Mountain area developed on Granodiorite.
Note the large residual boulders with sandy soil pockets
characterizing this area.

R. S. LaMotte L-135 to L-137

10/4/36



Wet meadow in lower Patterson Mountain granodiorite
area. Soil samples taken here.

R. S. LaMotte L-138

10/4/37

TEAKETTLE CREEK WATERSHEDS



Looking south across Teakettle Creek at lower end of Patterson Mountain area showing deep weathering and sandy soils developed upon granodiorite.

R. S. LaMotte L-139

10/4/36



From crest at lower end of Patterson Mountain area looking east across North Fork of Kings River. Miocene peneplane shows on the skyline. Foreground developed on granodiorite.

R. S. LaMotte L-140

10/4/36

TEAKETTLE CREEK WATERSHEDS



Looking up north fork of Kings River showing Granite Gorge in middle distance.

R. S. LaMotte L-141

10/4/36



Looking east across north fork of Kings River showing tributary canyon and hanging valley of Rancheria Creek. The latter was an area of normal erosion when the canyon in the foreground was occupied by the North Kings glacier during late Pleistocene time.

R. S. LaMotte L-142

10/4/36

TEAKETTLE CREEK WATERSHEDS



Looking east across the glacial trough of the North Fork, Kings River near its junction with the hanging valley of Rancheria Creek in the distance.

R. S. LaMotte L-143

10/4/36



The glaciated trough of the North Fork Kings River above its junction with Rancheria Creek.

R. S. LaMotte L-144

10/4/36

TEAKETTLE CREEK WATERSHEDS



Similar to L-143.
R. S. LaMotte L-145

10/4/36



Panoramic looking up Teakettle Creek drainages toward
Patterson Mountain showing lower portions of the Ex-
perimental area. Foreground and middle distance are
developed on granodiorite, far distance on Quartzite and
schist.

R. S. LaMotte L-146 to L-151

10/4/36



TEAKETTLE CREEK WATERSHEDS



Panoramic from lower end of Patterson Mountain water-
sheds to show glacial trough of the North Fork,
Kings River.

R. S. LaMotte L-152 to L-153

10/5/36



Looking across contact from granodiorite to Quart-
zite in middle Drainage 1.

R. S. LaMotte L-154

10/5/36

TEAKETTLE CREEK WATERSHEDS



Lower Drainage 1 wet meadow
and granodiorite outcrops.
R. S. LaMotte L-155 10/5/36



Lower Drainage 1 wet meadow
on granodiorite.
R. S. LaMotte L-156 10/5/36

TEAKETTLE CREEK WATERSHEDS



Middle Drainage 1. at
contact of granodiorite
and quartzite.

R. S. LaMotte L-157
10/5/36



Similar to L-157.
R. S. LaMotte L-158 10/5/36

TEAKETTLE CREEK WATERSHEDS



Panoramic at wet meadow on granodiorite below fault
contact with quartzite in middle drainage.

R. S. LaMo

159 to L-161

10/5/36



Ridge between Drainages 1 and 2. Basalt talus lying
upon granodiorite.

R. S. LaMotte

L-162

10/5/36

TEAKETTLE CREEK WATERSHEDS



Similar to L-162
R. S. LaMotte L-163

10/5/36



Similar to L-162
R. S. LaMotte L-164

10/5/36

TEAKETTLE CREEK WATERSHEDS



Similar to L-162.

R. S. LaMotte L-165

10/5/36



Details of pirate stream diverting water from
Drainage 2 to Drainage 3.

R. S. LaMotte L-166

10/23/36



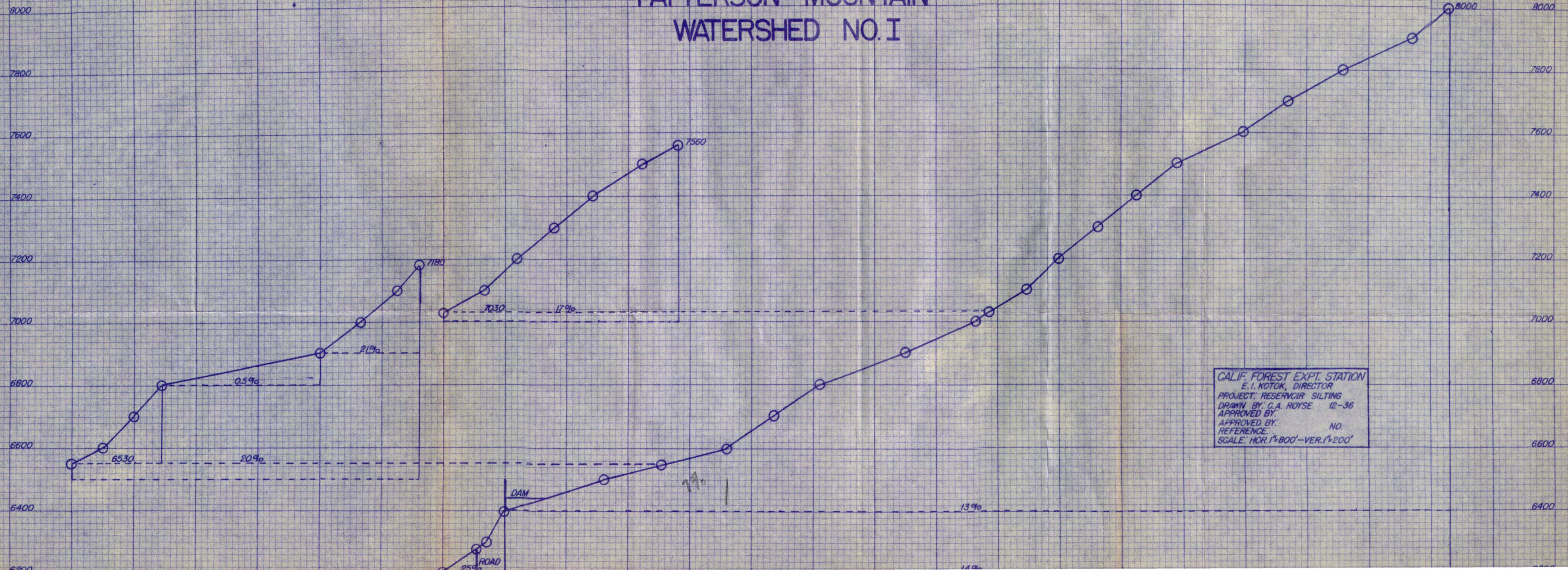
Figure (Harold Isgrigg) standing at spring in Drainage 3 which diverts part of runoff in Drainage 2 and introduces a case of incipient stream piracy above the proposed sites for dams. This stream represents probably 15% of the flow in Drainage 2. Colored by M. Sund.
R. S. LaMotte L-112 enlargement 10/4/36

TEAKETTLE CREEK WATERSHEDS

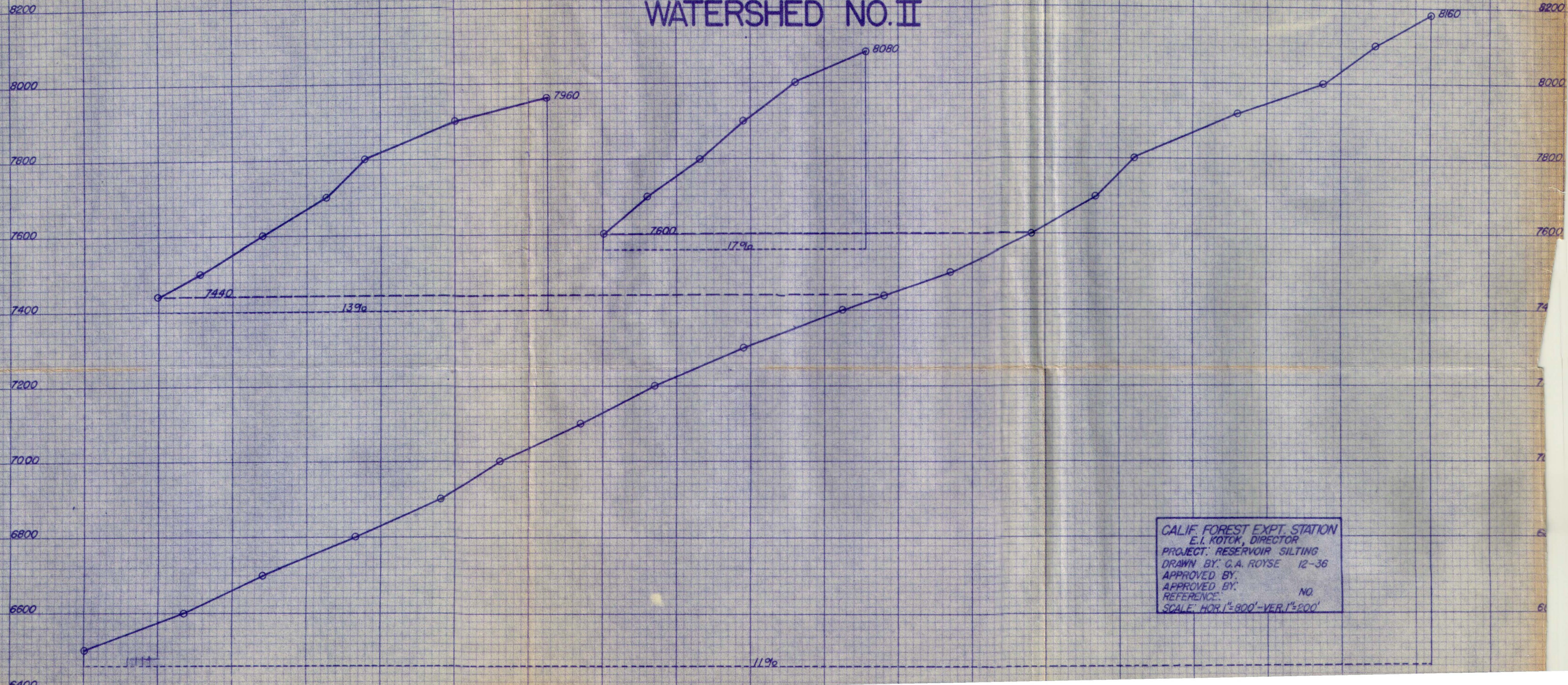


Details of pirate stream diverting water from
Drainage 2 to Drainage 3. Colored by M. Sund.
R. S. LaMotte L-166 enlargement 10//23/36

PATTERSON MOUNTAIN WATERSHED NO. I

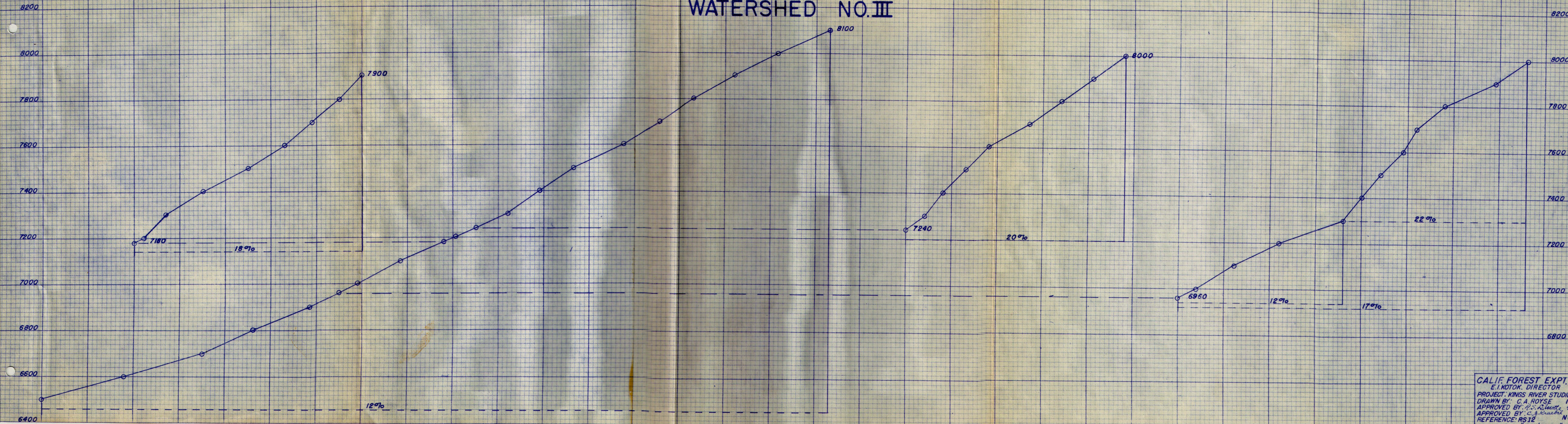


PATTERSON MOUNTAIN WATERSHED NO. II



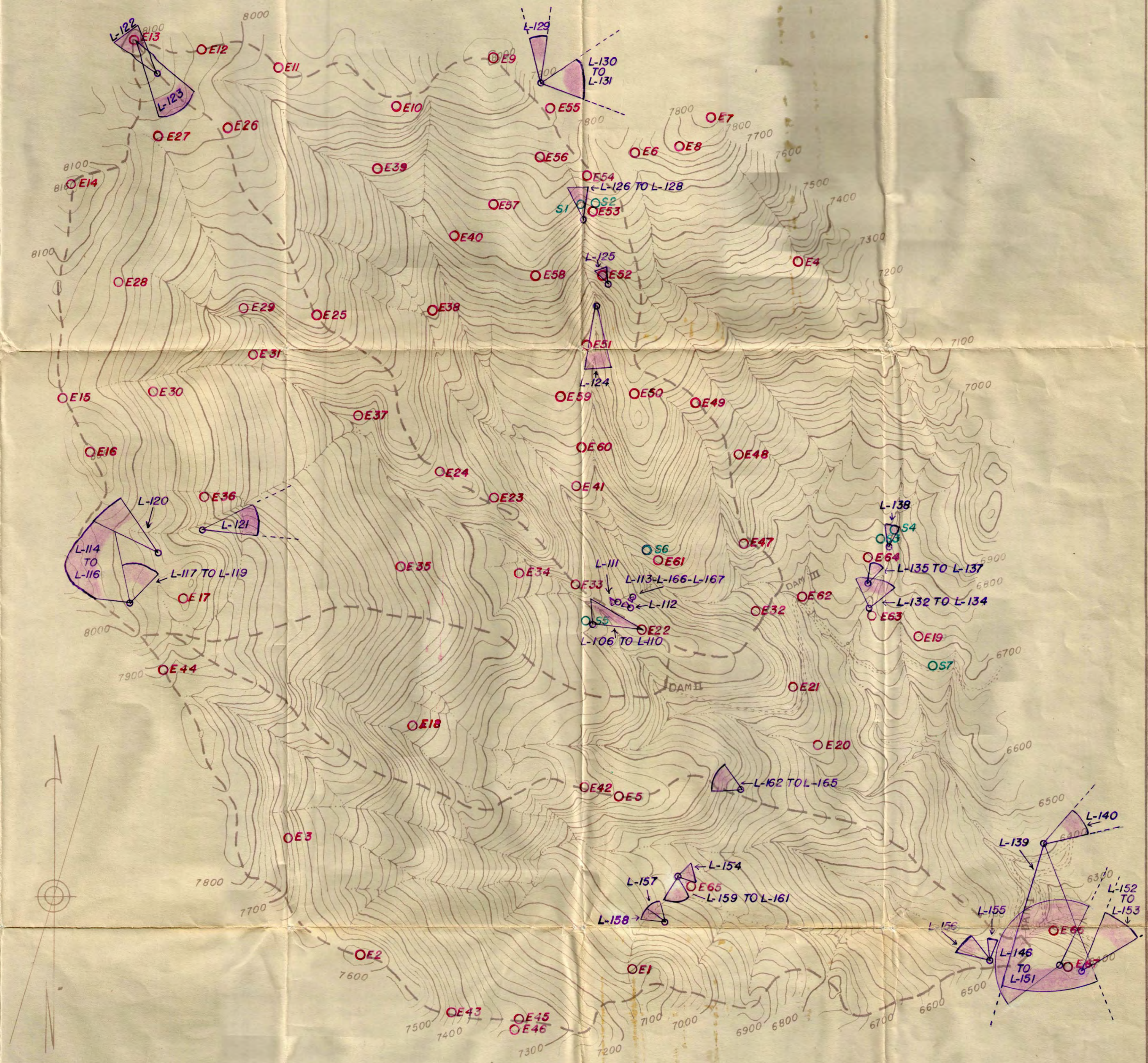
CALIF. FOREST EXPT. STATION
E.I. KOTOK, DIRECTOR
PROJECT: RESERVOIR SILTING
DRAWN BY: C.A. ROYSE 12-36
APPROVED BY:
REFERENCE: NO.
SCALE: HOR. 1"=800'-VER. 1"=200'

PATTERSON MOUNTAIN WATERSHED NO. III



CALIF. FOREST EXPT.
E. I. KOTOK, DIRECTOR
PROJECT: KINGS RIVER STUDY
DRAWN BY: C. A. ROYSE
APPROVED BY: P. S. R. [Signature]
APPROVED BY: C. J. [Signature]
REFERENCE: RS12

PHOTOGRAPHIC, ROCK & SOIL COLLECTIONS
PATTERSON MOUNTAIN WATERSHEDS
KINGS RIVER WATERSHED STUDIES
CALIFORNIA FOREST & RANGE EXPERIMENT STATION



800 400 0 800 1600 2400
SCALE: 1 INCH = 800 FEET
CONTOUR INTERVAL = 20 FEET

LEGEND

- OE1 ROCK SAMPLE
- △ SI1 SOIL SAMPLE
- L-115 PHOTOGRAPH
- WATERSHED BOUNDARY

U.S. DEPT. AGRICULTURE FOREST SERVICE
CALIFORNIA FOREST EXPERIMENT STATION
E. I. KOTOK, DIRECTOR
TITLE: PATTERSON MOUNTAIN WATERSHEDS
PROJECT: KINGS RIVER WATERSHED STUDIES
TOPOGRAPHER: E. W. KAEMMERLING DATE: MAY 1936
REVISED BY: R. S. LAMOTTE DATE: OCT. 1936
TRACED BY: C. A. ROYSE DATE: OCT. 1936
APPROVED BY: DATE:
APPROVED BY: DATE:
REFERENCE: DATE:
SC: 1 IN. = 800 FT. C. I. 20 FT. DRAWING NO.

AREAL GEOLOGY

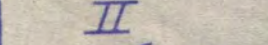
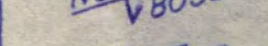
*PATTERSON MOUNTAIN WATERSHEDS
KINGS RIVER WATERSHED STUDIES
CALIFORNIA FOREST AND RANGE EXPERIMENT STATION*

QUATERNARY	Qm	5 - Pencil color	WET MEADOW-RECENT ALLUVIUM, SAND AND SILT IN VALLEY BOTTOMS
	Qf	9	DRY MEADOW-VALLEY FILL AND TERRACES, SAND, GRAVEL AND TALUS
	Ql	15	LANDSLIDE-LARGELY FRAGMENTAL BASALT AND QUARTZITE
	Tb	54	OLIVINE BASALT IN TWO FLOWS
	Grd	31	GRANODIORITE, QUARTZ-MONZONITE AND APLITE
TRASSIC OR MESOZOIC (EARTHLY) CARBONIFEROUS JURASSIC	Fl	23	LIMESTONE LENSES, CONTEMPORANEOUS WITH QUARTZITES AND SCHISTS
	FQ		QUARTZITE WITH MINOR AMOUNTS OF BIOLITE AND AMPHIBOLE SCHIST INCLUDES SOME APLITE.

AREA TABLE—ROCK TYPES

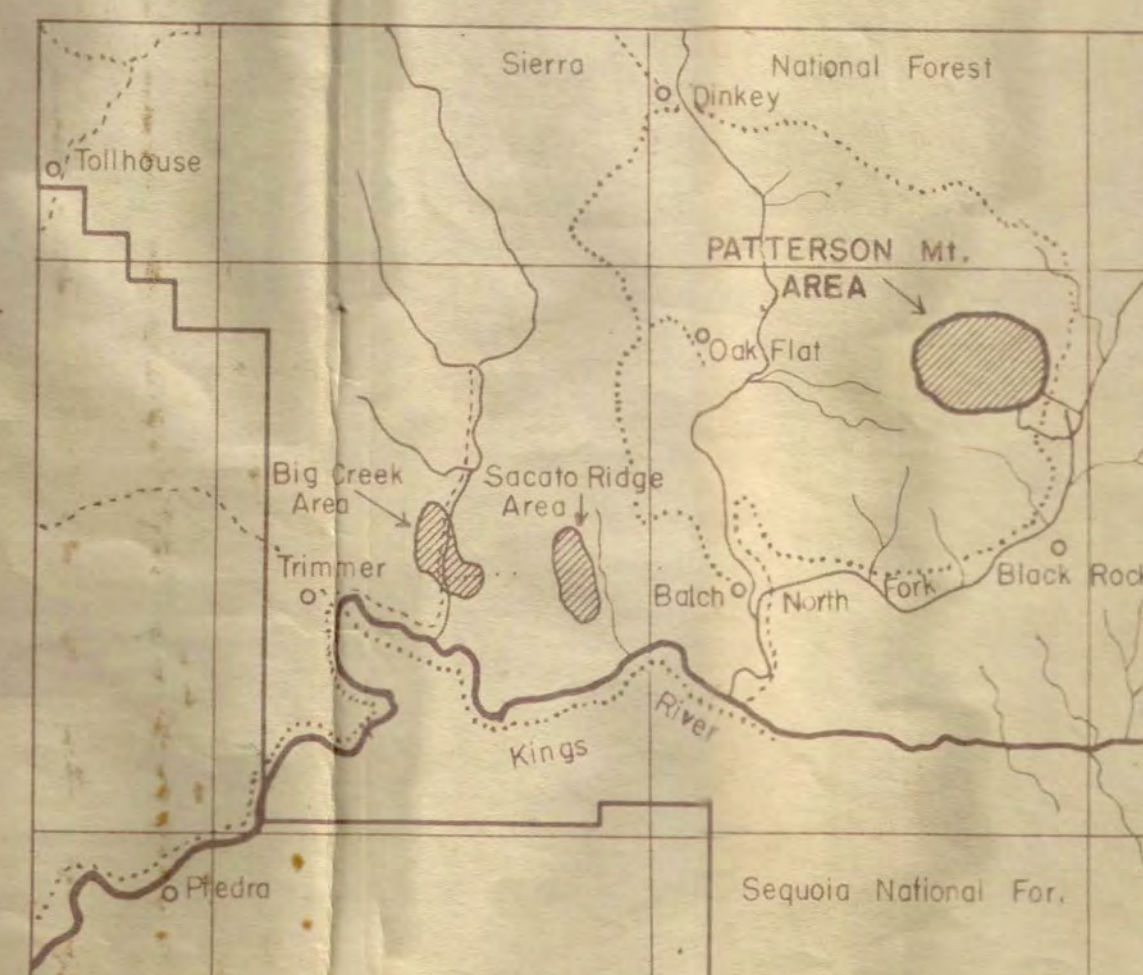
WATERSHED	Qm		Qf		Ql		Tb		Grd		Fl		FQ		TOTAL ACREAGE	PERCENT OF GRAND TOTAL
	PER- ACRES	CENT	PER- ACRES	CENT	PER- ACRES	CENT	PER- ACRES	CENT	PER- ACRES	CENT	PER- ACRES	CENT	PER- ACRES	CENT		
No. I	40.4	8				14.4	3	176.3	36	4.3	1	254.0	52	489.4	31	
No. II	38.3	7			7.3	1	51.9	10	1.1	.2		440.2	82	539.0	34	
No. III	50.7	9	.55	.1		6.2	1	28.9	5	1.2	.2	466.1	84	551.7	35	
TOTAL	129.4		.59		7.3		72.5		204.		5.5	1160.3		1580.		
PERCENT OF GRAND TOTAL		8		0.4		5		5	13		4		73		100	

LEGEND

- LEGEND**
- | | |
|--|--|
|  | (O) INTRUSIVE OR DEPOSITIONAL GEOLOGIC CONTACT |
|  | (C) FAULT GEOLOGIC CONTACT
GEOLOGIC CROSS SECTION |
|  | WATERSHED BOUNDARY |
|  | DAM |
|  | SERVICE ROAD |
|  | STREAMS |
| II | |
|  | DRAINAGE BASINS
STRIKE AND DIP |
|  | STRIKE, VERTICAL DIP |

NOTE: ALL STRIKES TAKEN FROM TRUE NORTH

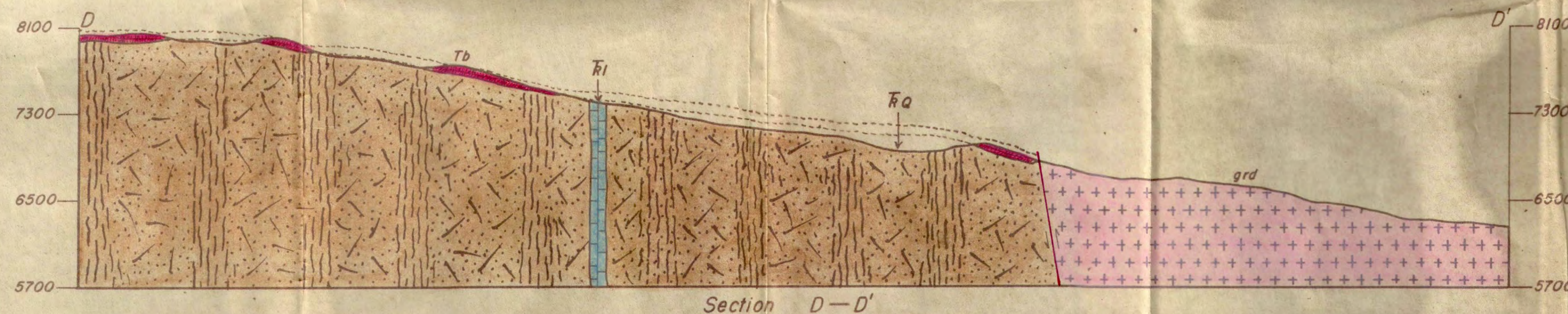
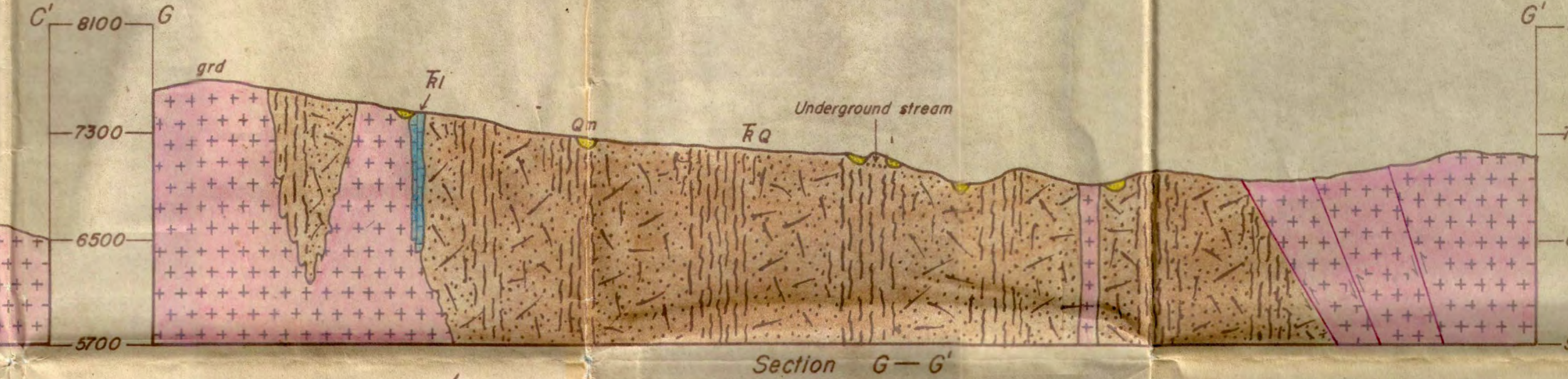
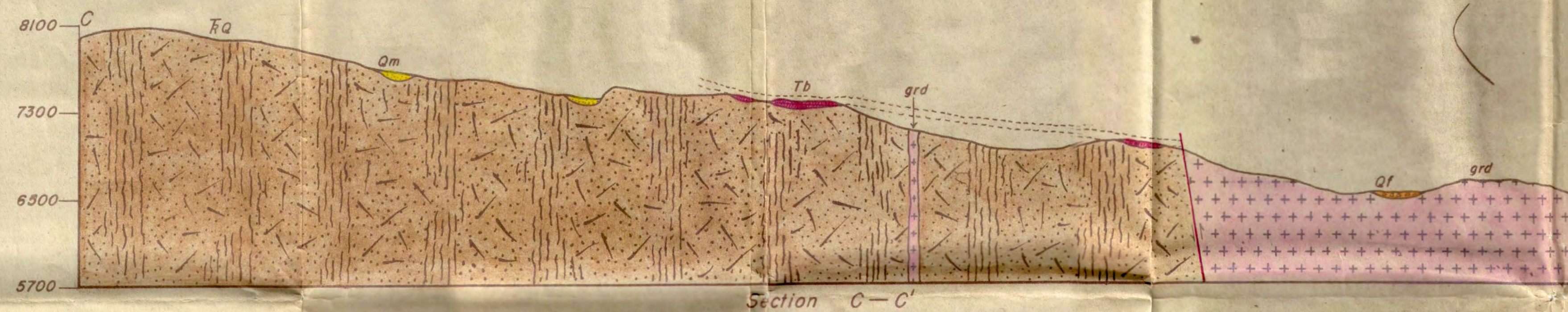
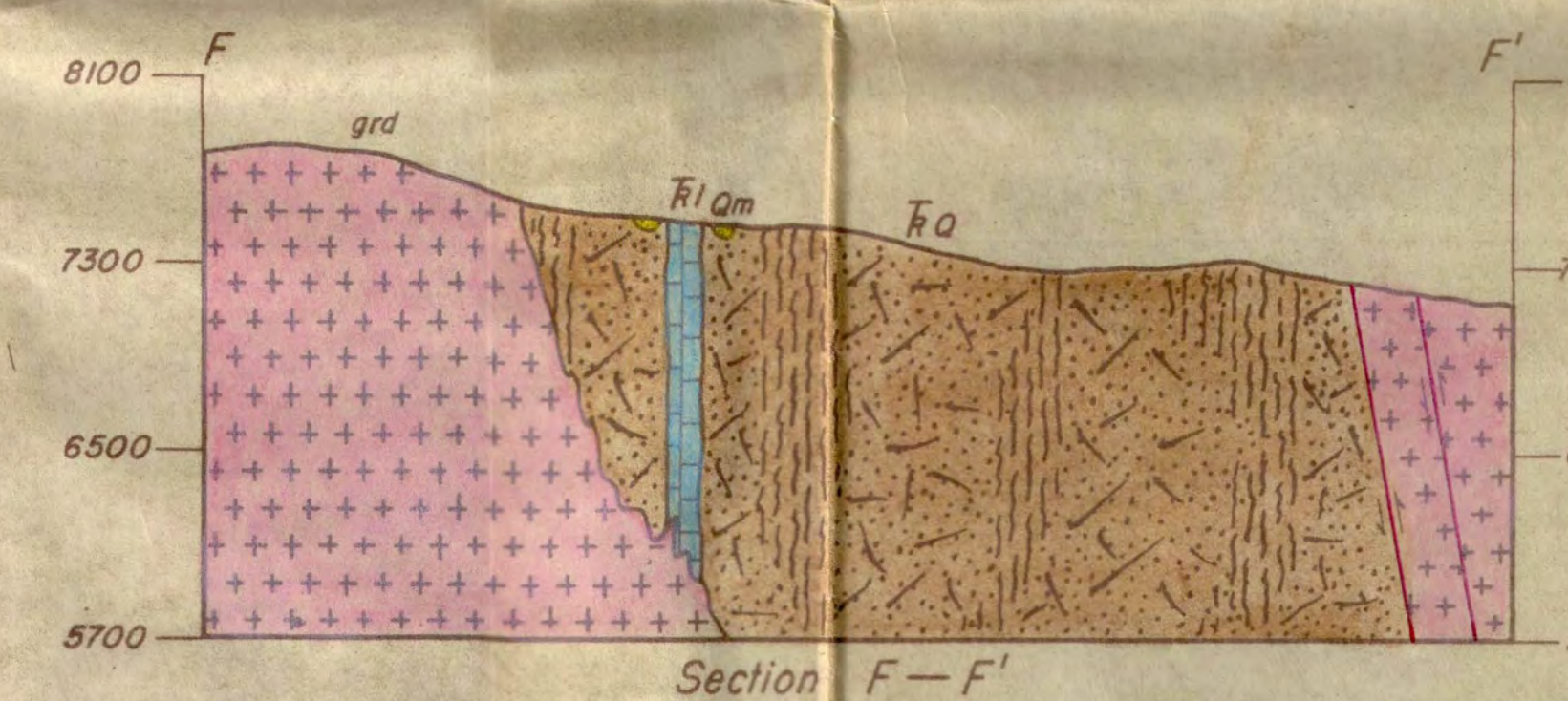
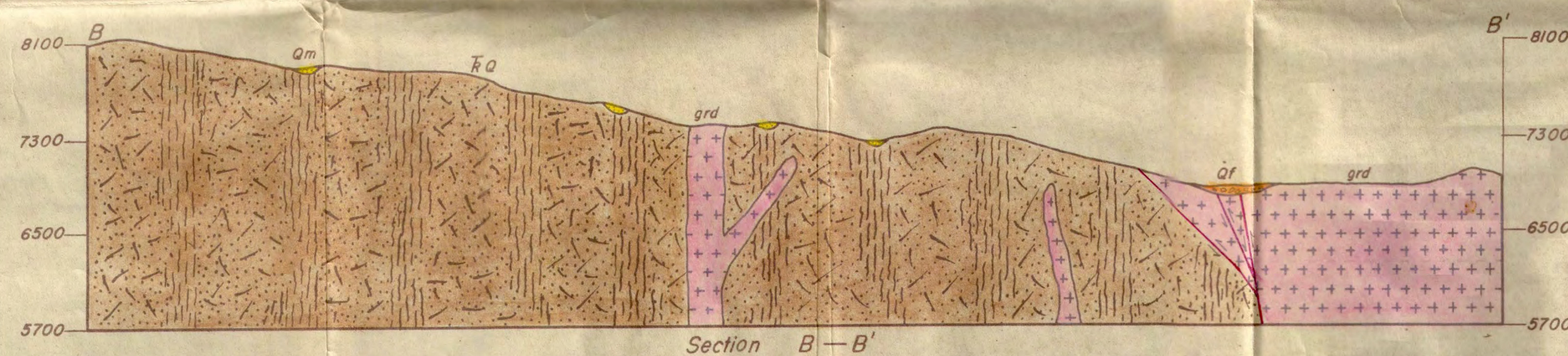
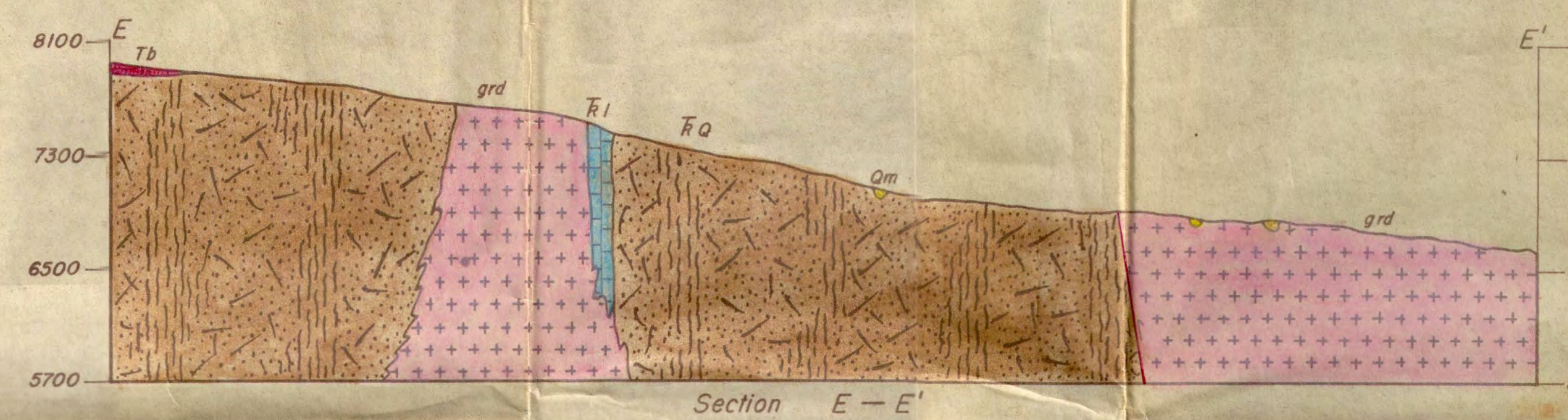
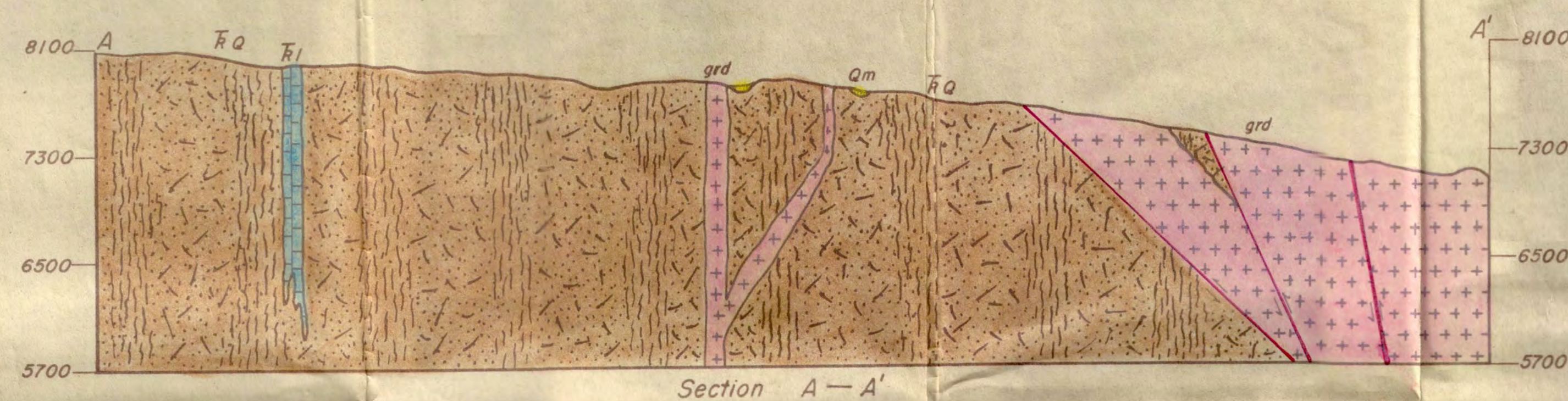
GEOLOGIC MAPPING BY: R.S. LaMOTTE, OCT. 1936.
TRACING BY: C.A. ROYSE, NOV.—DEC. 1936.



800 400 0 800 1600 2400
SCALE: 1 INCH = 800 FEET
CONTOUR INTERVAL = 20 FEET

U S DEPT. AGRICULTURE FOREST SERVICE
CALIFORNIA FOREST EXPERIMENT STATION
EIKOTOK, DIRECTOR
TITLE: PATTERSON MOUNTAIN WATERSHEDS
PROJECT: KINGS RIVER WATERSHED STUDIES
TOPOGRAPHER: E. W. KAEMMERLING DATE: MAY 1936
REVISED BY: R. S. LAMOTTE DATE: OCT. 1936
TRACED BY: C. A. ROYSE DATE: OCT. 1936
APPROVED BY: *W. M. Newman* DATE: 10/17/36
APPROVED BY: _____ DATE: _____
REFERENCE:
SC: 1 IN. = 800 FT. C. 1.20 FT. DRAWING NO.

GEOLOGIC CROSS SECTIONS PATTERSON MOUNTAIN WATERSHEDS KINGS RIVER WATERSHED STUDIES CALIFORNIA FOREST & RANGE EXPERIMENT STATION



NOTES: Dotted lines connecting the isolated patches of Tb in sections C-C' and D-D' indicate portions of flows that have been removed by late Tertiary and Quaternary erosion.

Elevations in feet—Datum is mean sea level.

U.S. DEPT. AGRICULTURE FOREST SERVICE
CALIFORNIA FOREST EXPERIMENT STATION
E. I. KOTOK DIRECTOR
TITLE: GEOLOGIC CROSS SECTIONS PATTERSON MOUNTAIN WATERSHEDS
PROJECT: KINGS RIVER WATERSHED STUDIES
DRAWN BY R. S. LaMOTTE DATE: NOV. 1, 1911
TRACED BY C. W. HOOVER DATE: NOV. 1, 1911
APPROVED BY H. M. MURPHY DATE: 12/1/11
REFERENCE
SCALE (Horizontal & Vertical) 1"=800' Dwg. No.