AREAL GEOLOGY OF THE SOUTHEAST PORTION
CHANCELLULLA PEAK QUADRANGLE, CALIFORNIA

A Thesis
Presented to the
Faculty of
San Diego State College

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
in
Geology

by
James Rodell Maytum
June 1967
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Approved by:

[Signatures and dates]
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CHAPTER I

INTRODUCTION

Location

The area investigated occupies the southwest part of the Chanchelulla Peak quadrangle (U. S. Geological Survey, fifteen minute series) in the extreme northwestern portion of Tehama County and the southwestern portion of Shasta County, northern California (Figures 1 and 2). Most of the land in this area consists of privately owned ranches, however, the westernmost portion is within the Yolla Bolly district of the Shasta-Trinity National Forests. The area can be approached from the Sacramento Valley either by State Highway 36 from Red Bluff or by the Ono road from Redding, both of which are paved. The Tedoc and Beegum Gorge gravel roads of the Forestry Service permit ingress into the mountainous western portion.

Field Work

Mapping in the field was conducted throughout most of Summer, 1965. This work was continued with some laboratory investigations in Fall, 1965 and Spring, 1966. Field mapping was done on aerial photographs (U. S. Department of Agriculture, nominal scale of 1:20,000). These data were transferred onto a topographic base consisting of the mapped portion of the Chanche-lulla Peak quadrangle which was enlarged to a scale of 1:24,000.
FIGURE 1
INDEX MAP OF NORTHERN CALIFORNIA SHOWING COUNTY BOUNDARIES. ARROW POINTS TO THESIS AREA.
FIGURE 2

OUTLINE OF 15 MINUTE GEOLOGICAL SURVEY QUADRANGLES REFERRED TO IN THE TEXT. MAPPED AREA SHOWN BY HATCHING.
Previous Investigations

Only recently have authors given detailed treatment to this portion of California geology. Most of the earlier writers limited their studies to regional investigations of the basement complex or the sedimentary rock units. Irwin (1960, p. 12 and 21) has presented a detailed summary of the evolution of geologic studies in the Klamath Mountains metamorphic belts. Many of these early investigations were involved in reconnaissance economic surveys of northern California. Of particular importance to this area was Hershey (1901, 1906) who presented the first general description of the rocks of the western Paleozoic and Triassic belt. He studied the portion of the Klamath Mountains complex that makes up the metamorphic basement of this report. Much of this work was later modified by Diller (1903), Hinds (1932, 1934, 1935), and Maxson (1933). Each successive author added something to the general regional geologic knowledge but left a number of conflicting ideas.

Irwin and Tatlock (1956) and Irwin (1960) compiled a regional geologic map of northwestern California. The general outlines which were presented are essentially those which are presently accepted. Recently Merriam (1961) and Silberling and Irwin (1962) have examined the limited paleontologic data and have arrived at a probable Triassic age, at least for that portion of the basement which is presented in this report. Very
recent publications include those which deal with regional
correlation (Davis et al., 1965) and with the problems of the

The overlying sedimentary units have a complicated history
of study. The earliest studies of these Jurassic (?) and Creta­
ceous units are among some of the most classical works on Cali­
fornia geology. The most important include the paleontological
studies by Gabb (1864, 1869) and White (1885). The initiation
of stratigraphic studies was by Diller and Stanton (1894). The
first detailed geologic mapping was done by Diller (1906) as a
Geological Survey folio for the old Redding quadrangle. Anderson
was by far the most prolific student of Cretaceous paleontology
and stratigraphy. His biostratigraphic classifications (Anderson,
1933, 1938, 1945) were retained until modified by Murphy (1956).
The most recent lithostratigraphic revision (Murphy et al., 1964)
has been essentially accepted by this writer.

The only specific references to the map area include work
on the structural geology and sediment distributions in the
northern portion (Murphy et al., 1964; Bailey and Irwin, 1954;
Bailey et al., 1964). To the south of this area there have been
a number of unpublished theses (including Harrington, 1942);
Dondanville, 1958; Raymond, 1958; Young, 1958) which provide
some insight into the Knoxville-Budden Canyon formational rela­
tionships. Recently Lachenbruch (1962) has reviewed the geology
and some of the geologic studies of western and northwestern Sacramento Valley.

**Regional Setting**

The mapped area falls at or near the boundaries of three northwestern California geologic and geomorphic provinces. Although the detailed outlines of the Klamath Mountains, the northern Coast Ranges, and the Sacramento Valley provinces have been somewhat argued, they are generally agreed to exist as presented by Figure 3 of this report.

Within the map area there are two distinct gross lithic units. Along the western portion of the area and in the northwestern portion the rocks of the Klamath Mountains metamorphic complex are exposed and are referred to as the "basement complex" in this report. Regionally, the most striking feature of these rocks is their arrangement into four concentric arcuate belts which are generally concave to the east (Irwin, 1960, p. 14). This pattern includes: 1) the western belt; the westernmost portion of the Klamath province, generally consisting of middle-Late Jurassic rocks, 2) the western Paleozoic and Triassic belt; the portion of the complex which represents the basement units of this area, 3) the central metamorphic belt; consisting of the oldest rocks in the Klamath Mountain complex and possibly, in part, a metamorphic facies of the adjacent belts, and 4) the eastern Paleozoic belt; made up of the most studied rocks of the
FIGURE 3

SMALL SCALE GEOLOGIC MAP OF NORTHERN CALIFORNIA
FROM A PORTION OF U. S. GEOLOGICAL SURVEY MGI 1-512.
SCALE: ONE INCH EQUALS APPROXIMATELY FORTY MILES.
THESIS AREA IS OUTLINED.
province with exposures representing the Silurian and Mississippian periods. These units differ from each other not only in their geologic histories, but also in their lithology structure, and degree of metamorphism.

In the southern portion of the Klamath Mountains the trend of these geologic belts is generally northwesterly. In the mapped area, and in surrounding areas, rocks of the western Paleozoic and Triassic belt consist of slightly metamorphosed detrital sedimentary and volcanic rocks with some chert and subordinate amounts of limestone. The structure here is complex and difficult to interpret because of poor exposures. It does, however, seem to follow the general structural grain of the belt.

The numerous intrusions, ranging in composition from intermediate to ultramafic, are of considerable interest. The largest of these is the Shasta Bally diorite batholith which is located to the northeast of the map area. It has been studied in some detail and has been dated as being very late Jurassic, probably related to the Nevadan orogeny (Curtis et al., 1958; Larson, 1958). When reviewed regionally, the distribution patterns of the various intrusions tend to follow the large scale grain of the province (Irwin, 1960, Plate 1; Strand, 1962). The larger faults of this province generally further define this grain and in many places form the boundaries between intrusive bodies and country rock and between some rock units of different
regional belts.

Less intensely studied are the large number of ultramafic occurrences within this province, usually consisting of peridotite bodies of various sizes which have been at least partly altered to antigorite serpentine. The age of these rocks is known only to be pre-batholithic; probably Upper Jurassic (Irwin and Lipman, 1962, p. C21). Within the mapped area are minor amounts of gabbro, diorite, peridotite, and serpentine.

Although Hinds (1952, Plate 2) and others have included the tilted sedimentary rocks of the northwestern portion of the Sacramento Valley in the northern Coast Range province, this writer feels that on the basis of geologic history and general lithic relationships most of them should be included in the "Sacramento Valley succession." The included formations range in age from Late Jurassic to Late Cretaceous and are composed chiefly of graywackes and shales. In the extreme northwestern portion of the Sacramento Valley only Lower Cretaceous, and possibly uppermost Jurassic, strata are represented. These lie directly upon the rocks of the western Paleozoic and Triassic belt of the Klamath Mountains metamorphic province, but are separated from them by a marked unconformity. Most of this part of the Sacramento Valley succession is included in the Budden Canyon Formation (Murphy et al., 1964) which ranges in age from Lower Cretaceous (Hauterivian) to Upper Cretaceous (Turonian;
Popenoe et al., 1960, Chart 10e, after Murphy, 1956). The Lower Cretaceous strata are particularly notable in that although rocks of this age are known to extend into British Columbia, in no area are they so extensive as in the northwestern Sacramento Valley. Locally these units are very fossiliferous. Although the sedimentation history is almost continuous, Peterson (1963, p. 4634; 1964, p. 270) has defined a number of unconformity-bounded sequences. The sequence represented within the map area is that of Neocomian age. The Lower Cretaceous shales, mudstones, graywackes, and conglomerates have been estimated to range in thickness from 10,000 to over 20,000 feet along the Shasta-Tehama county line (Lachenbruch, 1962, p. 58; Murphy et al., 1964) and closely resemble the lithologies of the older Knoxville strata which they overlie.

Structurally, the area of the northwestern Sacramento Valley is a broad plunging syncline. Along the west side of the valley, Mesozoic rocks are exposed in a series of long strike ridges and valleys which trend in a north-south pattern. The units dip at a variable steep angle to the east. Toward the north, at the terminus of the Coast Range province in the northwestern Sacramento Valley, the strike of the stratal units bend to form the northwest-trending axis of the large scale syncline (Irwin, 1960, Plate 1; Lachenbruch, 1961, Plate 2; Strand, 1962). The portion which this report includes is located on the southern
limb of this syncline, on the contact of the sedimentary and metamorphic units.

Faulting in the sedimentary rocks is generally limited to basement generated fractures of limited linear extent. These usually die out within a short distance in the sedimentary succession. Jointing, much of which is systematic and related to the fault pattern, seems to be related to both regional and local deformation. There is no evidence to suggest that there are any faults in the northwestern Sacramento Valley of a scale comparable to the regional longitudinal fault which forms the contact between much of the Franciscan Formation and the Knoxville Formation along the west side of the valley (Taliaferro, 1943).

Geomorphology

There have been no references in the literature to the geomorphology of the mapped area. Regionally, however, it has been treated in several works which are here summarized. The Klamath Mountains province is an area dominated by deeply truncated mountains that follow a general northwesterly to northerly trend only when viewed on a regional scale. Most of the drainage is dendritic and is unrelated to the structural and lithologic trends of the province. Throughout the province there are present remnants of several old erosional surfaces of considerable areal extent. These remnants usually take the form of
elongate broad ridge crests with similar elevations along the same ridge.

The eastern margin of the Coast Ranges and the western and northwestern portions of the Sacramento Valley have a similar geomorphic appearance. That is, they both have lithologically and structurally controlled ridges and valleys with a generally concordant drainage pattern. Here, the average altitude is lower than the Klamath Mountains and the topography is more subdued. There are reports of evidence for similarities in regional erosion surfaces with the Klamath Mountains (Irwin, 1960, p. 13), however, because of the rather recent Coast Range orogenies these may be largely disrupted.

Regional studies indicate that at some time in the late Pleistocene (post-Wisconsin), all of the streams which drain into the Sacramento Valley started active downcutting. Harrington (1942, p. 33) attributed this to a lowering of stream base level, however, the late Pleistocene uplifts of the northern Coast Ranges may just as well have been the cause. Such orogenic rejuvenation probably increased the gradient of other stream channels in the Coast Ranges (particularly see Gealey, 1951, Plate 4). Eustatic fluctuations cannot alone be invoked to explain late Pleistocene downcutting because at the end of the glacial period there was a general rise, now a lowering, of sea levels.
Those streams whose source was in the mountains carried the most water and were therefore more competent to cut back into the mountain front and into the soft shale belt in front of it. Within the map area such streams are represented by Beegum Creek, and, to a lesser extent, by Wells Creek. These larger streams are less influenced by the geologic arrangement of the rocks over which they flow than the ones which have their source as small springs within the sedimentary succession. The larger streams tend to cut discordantly across the geologic grain and to flow east as soon as their channels cross onto the softer sedimentary rocks from the resistant basement complex. Within the basement rocks of the Klamath complex, even the largest streams, as Beegum Creek, are influenced by certain resistant units. Numerous hard cherty layers have produced a marked pseudo-meandering effect in Beegum Gorge.

The more resistant conglomerate and sandstone units of the Sacramento Valley sedimentary succession form effective barriers only against the smaller, ephemeral streams. These streams, which are fed by small springs or by direct runoff, tend to flow parallel to the resistant ridges. Since the map area is located on a bent homocline, these resistant ridges produce a rather curved trellis drainage pattern.

Appreciable quantities of alluvial material are lacking in all of the stream channels and canyons of this area. Those
gravels which are present seem to be restricted to the immediate watercourses. All streams are actively downcutting with no significant amounts of deposition occurring. Rapid downcutting of stream channels has produced canyons and small valleys that lack many terraces. Those terraces which do occur are limited to the strath type with a very thin alluvial veneer on an eroded bench. Several of these terraces can be seen along Beegum Creek, particularly near the old Beegum bridge, where they are situated about twenty feet above the present stream and are covered with a two foot-thick layer of sand, soil and gravel. The gravel covered terraces on the Middle Fork Cottonwood Creek (about one mile north of Platina) are better developed. Although none of the terrace systems are very extensive, it would appear that the Beegum terraces are correlative with the Cottonwood terraces on the basis of similarity of scale, height above stream, and thickness of veneer.
CHAPTER II

BASEMENT COMPLEX

General Relations

The rocks of the southern portion of the western Paleozoic and Triassic belt of the Klamath Mountains province underlie the entire transgressive Mesozoic sedimentary succession and have contributed a significant portion of the clastic material found in the overlying units. The basement complex of the map area is made up chiefly of sedimentary and volcanic rocks, all of which have been subjected to some degree of metamorphism. Intrusions of both mafic and ultramafic composition are also present.

The exposures of most basement units in this area are poor and are usually limited to the bottoms of the larger creeks, to road cuts, and to certain ridge outcrops. Therefore, although the general distribution of the rock types is known, the actual contacts between some of the units is interpretive.

Rocks of the basement complex have been mapped according to their gross lithologic type (e.g., as metasedimentary, volcanic, and intrusive). Only when special rock bodies deserve special attention have they been separately distinguished. This is particularly true in the cases of some of the limestones, peridotites, and larger intrusive units.
Age and Correlation

The geologic age and regional relations of the basement complex are difficult to realize because of the scarcity of recognizable fossil material, the structural complexity and poor exposures, and the lack of detailed areal studies. Irwin (1960, p. 20) has summarized the earlier works which have been conducted throughout the western Paleozoic and Triassic belt to determine the ages and the relationships of the various units. Figure 4 of this report is included to present graphically the conclusions of several previous workers.

Hershey (1901, 1906) divided what is known as the western Paleozoic and Triassic belt into two different "series". His Lower Slate of Devonian-Carboniferous age can be extended southward from Humboldt County to the southeasternmost portion of the belt, and hence the area of this study. This early work was supported by Diller (1903) who studied the paleontology of the limestone units at several locations. Diller's Southwestern Carboniferous belt (1903, p. 344) is correlative to the Lower Slate of Hershey. Of special importance to the southern portion of the western Paleozoic and Triassic belt is the work of Hinds. Here, the altered cherts, schists, metaconglomerates, and marbles were assigned to the Chancelulla Formation of supposed Devonian age (Hinds, 1932, p. 392).

Until recently, all of the ages which were assigned to
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<th>Hinds</th>
<th>Miller Merriam Silberling</th>
<th>Davis</th>
<th>This Report</th>
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<td>Lower Slate Series, Carboniferous.</td>
<td>Carboniferous Belt.</td>
<td>Chancelula Formation, pre-Copley greenstone (Devonian).</td>
<td>Late Triassic.</td>
<td>Applegate Formation, Triassic (?).</td>
<td>Middle Permian to Late Triassic (?).</td>
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* Hershey (1901)  
  Diller (1903)  
  Hinds (1932)  
  Miller, Furnish, and Clark (1957)  
  Merriam (1961)  
  Silberling and Irwin (1962)  
  Davis et al. (1965)

**FIGURE 4**

DIAGRAM OUTLINING AND COMPARING THE NOMENCLATURE FOR THE AGE RELATIONS OF THAT PORTION OF THE WESTERN PALEOZIOC AND TRIASSIC METAMORPHIC BELT WHICH IS EQUIVALENT TO THE BASEMENT COMPLEX OF THE SOUTHEASTERN PORTION OF THE CHANCELLULLA PEAK QUADRANGLE.
this belt were taken largely from the original fossil identifications by Diller (1903). However, Merriam's recent re-examination (1961) of some of Diller's ammonites points to a probable Triassic age (rather than Carboniferous). Although Merriam's study was limited to the fossils which had been collected along the southwest margin of the belt, it casts serious doubts on the validity of many of the early age determinations throughout the province.

Of particular interest are the studies of the fossils from the Wildwood (Hall City Caves) limestone area in northeastern Dubakella Mountain quadrangle and the Whiterock limestone area in southeastern Dubakella Mountain quadrangle (Figure 2). Merriam's work (1961, p. C188) indicates that the Whiterock fossils of Diller are actually arcestids (instead of ammonites) of Triassic age. The Wildwood collections are less certain but seem to be of a Permo-Triassic age.

Independent and slightly earlier studies on several well preserved ammonites from the Wildwood limestones point to a Middle or Late Permian age (Miller et al., 1957, p. 1062). The most recent paleontologic work near this area, however, supports the studies of Merriam with a slightly later date of Triassic. Silberling and Irwin (1962, p. B60) examined the Whiterock locality in detail and revealed a surprisingly diverse and well preserved fauna, some being diagnostic Late Triassic ammonites.

Irwin (1960), in his reconnaissance of the Klamath
Mountain province, based the upper age limit of the western Paleozoic and Triassic belt on the work of Miller et al. (1957) and the yet unpublished records of Merriam and Silberling. The ages presented by all of these authors is recognized to be positive only for the limestones, however, they are also assumed to apply to at least some of the other rocks, particularly those which surround the limestone bodies.

Mapping in southwestern Oregon has shown that the units of the western Paleozoic and Triassic belt extend northward that far. Here, Wells et al. (1949) assigned fossiliferous Triassic limestones to the Applegate Group. Very recently, Davis et al. (1965, p. 950) have mapped the Triassic (?) greenstones and metacherts in the south-central Klamath Mountains as Applegate Formation. This latter area is less than fifty miles north of the area referred to in this report. The petrographic and structural descriptions of the rocks in the south-central Klamath Mountains have marked similarities to those of the units which were studied for this report. For this reason, the rocks of the western Paleozoic and Triassic belt which form the basement complex of the map area are assigned to the Applegate Formation. The probable age range of Middle Permian to Late Triassic has been chosen by this writer and was based on the recent paleontologic work of Miller et al. (1957), Merriam (1961), and Silberling and Irwin (1962).
The age and genetic relationships of the igneous intrusive rocks of the map area present a somewhat different problem in that it is not possible to correlate directly the mapped exposures with those that have been dated. Because they all cut through, and alter the metamorphic rocks, the intrusions must be post-Late Triassic. Also, within the map area, both the basic and ultrabasic intrusives are unconformably overlain by the sedimentary rocks of the Early Cretaceous Budden Canyon Formation and possibly the latest Jurassic Knoxville Formation (Portlandian). If the lowest sediments indeed are Knoxville, the intrusions are probably no younger than Kimmeridgian.

The ages of the intermediate and basic intrusions of the Klamath Mountains have been in part determined by a number of workers including Curtis et al. (1958) and Larson (1958) by radiometric methods, and Rodda (1959), Irwin (1960) and Davis, et al. (1965) by superposition. Quartz diorite from the Shasta Bally batholith has been dated as 134 million years old (Curtis et al., p. 5; by Potassium-Argon methods) and as 81 to 112 million years old (Larson, p. 50; by Lead-alpha methods).

Using stratigraphic relations, Rodda (p. 16) indicates a Late Jurassic to Lower Cretaceous (Hauterivian) age for the Mule Mountain and Shasta Bally batholiths in the French Gulch-Ono area of Shasta County. The upper possible limit is well defined because these igneous rocks are overlain unconformably by the
Hertleinities aquila zone of Murphy (1956). Davis et al. (1965, p. 961) agrees with a Late Jurassic to Early Cretaceous age for the intrusives in the south-central part of the Klamath Mountains. Most workers seem to feel that the intermediate and basic intrusive activity of the southern Klamath Mountains was directly related to the Nevadan orogenic epoch (Kimmeridgian to late Tithonian).

The gabbroic and dioritic intrusions of this map area are probably related to these other larger bodies. In the area of Walker Point (west-central portion of map area), the Knoxville Formation (?) conglomerate member overlies both the Walker Point stock and the metasedimentary basement rocks, both occurring at the same elevation. The intrusion is therefore pre-Portlandian, the age of the Knoxville.

There is no way to date the several small, discordant, basic dikes in the area except to say that they intrude the basement complex and that there have never been any reported in the sedimentary succession of the northwestern Sacramento Valley. They are assumed by this writer to be genetically related to the same phase of activity which produced the previously mentioned intrusions.

Finally, the ultramafic rocks of this area present a special problem in age determination. They consist mostly of peridotite derived antigorite serpentine and some slightly
altered peridotite. These rocks have been the subject of considerable study in the surrounding region (including Rynearson, 1944; Dondanville, 1958, p. 2; Irwin, 1960, p. 15; Irwin and Bath, 1962; Irwin and Lipman, 1962; Davis et al., 1965, p. 4). There has, however, been a general trend to concentrate on the petrographic or economic (chromite) aspects of these rocks rather than on their age or mode of formation. For reasons which will be presented in the section on ultramafic petrology and structure, these rocks in the mapped area are considered to be more closely related to the ultramafic rocks of the Klamath Mountains than to those of the northern Coast Ranges.

Irwin and Lipman (1962, p. C18) have demonstrated that the ultramafic rocks in the Klamath Mountains are the remnants of a once continuous, subhorizontal sheet of peridotite which may have been intruded along a regional unconformity or brought in by thrusting during some phase of activity before Late Jurassic (Kimmeridgian-Tithonian) time. The pre-latest Jurassic limit of Irwin and Lipman is probably based on the fact that intrusive rocks (such as the Shasta Bally batholith northwest of Ono) of known Late Jurassic age have intruded and contain inclusions of the ultramafic rocks. Because the ultrabasic rocks intrude units of Early Mesozoic age, the lower limit of the peridotite-serpentine age probably lies somewhere in the Jurassic.

To the south, the serpentines of the northern Coast Ranges
are known to have been emplaced in the Late Jurassic (between middle Kimmeridgian and middle Tithonian) because of their relationship with the fossiliferous sedimentary succession which they intrude along the west side of the Sacramento Valley (Irwin, 1960, p. 58). This information, along with various field evidence, suggests that the ultramafic rocks were emplaced during the same general interval of activity which produced the other intrusive rocks, with the ultramafic rocks preceding the others.

**Petrology and Distribution, Applegate Formation**

Although the Permo-Triassic (?) members of the western Paleozoic and Triassic belt are extremely varied and complex, the rocks within the map area exhibit remarkable similarities to those described elsewhere in the belt. In his review of the entire Klamath Mountains province, Irwin (1960) reported that the typical assemblage of the belt in general consists dominantly of mildly metamorphosed clastic sedimentary rocks, limestone, chert, and metavolcanic rocks. The fine-grained sedimentary rocks are chiefly slaty which, with the chert, constitutes the bulk of the belt; the proportions of these are somewhat different in the Applegate Formation however. Both in this area and in the south-central portion of the Klamath Mountains the dominant rock types are quartzite, greenstone, metachert, and subordinate amounts of fine-grained meta sedimentary rocks.

All of the rocks in the Applegate Formation in this area
have been subjected to some degree of regional metamorphism. In
certain limestone bodies, mechanical deformation has produced a
kinetic metamorphism which has exceeded the chemical alteration,
however this has taken place on a rather restricted scale. The
entire metamorphic complex in this area has not been subjected
to alteration any more extensive that that of the greenschist
facies, with the exception of the contact metamorphic aureoles
which surround the Walker Point and Coyote Gulch intrusives.
Aside from the petrographic evidence of the chlorite-rich green-
stones, the well preserved bedding features of the metasedimentary
units and the unaltered nature of many of the limestones all indi-
cate a low pressure-temperature condition during metamorphism.
There is no evidence to suggest that any of the metamorphic rocks
of this area were ever subjected to alteration in the epidote-
amphibolite facies range. On a small scale these rocks display
a number of metamorphic structures, including foliation, rock
cleavage, and some bedding fissility.

Rocks of an originally sedimentary origin are the most
common constituents of the metamorphic complex. These are grouped
under the general mapping unit of metasedimentary rocks and repre-
sent a wide variety of different rock types. In the northwestern
portion, particularly along the Ono-Platina road, most of the
metasedimentary rocks are quartzite. These are highly weathered,
but still exhibit well defined remnant bedding in many places.
These quartzites are very dark in color with a freshly broken fragment being brown to dark gray. Most of the rocks exposed at the surface are covered with a secondary, lighter red-brown, earthy residue.

These quartzites in the northwest generally fit the compositional and textural description given by Irwin (1960, p. 22) for other quartzites in the belt. They consist mostly of slightly deformed quartz grains with undulatory optical extinction, a few rather angular chert fragments, and only minor amounts of potassium feldspar and plagioclase. The chief difference in this area is that these quartzites contain a relatively higher percentage of the ferro-magnesium minerals; these are responsible for the dark color. Bands of gray-black argillite are directly associated with these quartzites. Much of the argillite has a silky, submetallic lustrous coating on the fracture surfaces. Where well exposed, both the quartzites and the argillites exhibit a generally common strike. This strike tends to follow the northwesterly grain of the western Paleozoic and Triassic belt.

Of a distinctly different nature is the occurrence of light green quartzite which is exposed for five hundred feet west from the new Beegum bridge. This massive unit has only minor fractures and is one of the most resistant which is exposed in Beegum Gorge. It is of particular interest because it is the
only occurrence of this sort of rock which was seen by this writer and because the Lower Cretaceous Rector Member conglomerate seems to contain clasts of exactly the same material.

A metaconglomerate unit which is exposed in a road cut in section 15, T. 29 N., R. 9 W. is of interest because of the rarity of this rock type in the area. This unit is definitely part of the basement complex because it is bounded (non-faulted) by other metasedimentary rocks. The subrounded clasts range in size up to two feet in diameter and appear to have been partly metamorphosed before their inclusion in the conglomerate. They are composed of highly altered volcanic and possibly plutonic rocks and some schist. The entire unit was metamorphosed with the surrounding members, at which time most of the bedding features were destroyed. This unit also occurs as a highly altered and pyritized pendant in the Walker Point stock.

In the central-western and southwestern portions of the area various cherty units are more common than quartzite. Considering the entire western Paleozoic and Triassic belt, cherts are probably the second most abundant sedimentary rock after the slates (Irwin, 1960, p. 22). The cherts may actually be more common than formally recognized because of a tendency to become more granular upon recrystallation. It is therefore possible that many cherts may be mistaken for quartzites in the field. That material which can be definitely identified as chert in
this area occurs in a number of different forms and colors. Most commonly, however, it appears in variably thick units which are made up of many rather uniform, one to three inch thick beds of a gray color. Some of the cherts are also massive with individual beds up to three feet in thickness. These latter types are usually dark green or brown in color.

Along Beegum Gorge the bulk of the metasedimentary material is composed of thick units of thinly bedded chert. Interbedded with these are argillite units whose laminations are generally thinner than the chert. The cherty units range up to 250 feet in thickness while the argillaceous interbeds seldom exceed fifty feet. The units never appear to be schistose and the foliation is always parallel to the plane of remnant bedding. This argillite comes the closest to the slates which have been described as the most common rock type in other areas of the western Paleozoic and Triassic belt. Nowhere, however, in this area are there any amounts of argillite to compare with the percentages outlined by Irwin (1960, p. 22) as being representative for the entire belt.

A singularly interesting occurrence of chert is in section 28, T. 29 N., R. 9 W. along Beegum Creek where the rock can be found as thin, irregular beds, lenses, and stringers in a dense and crystalline limestone. The chert is dark green. The bands are all subparallel and tend to define the attitude of the larger
limestone unit which may be as thick as 500 feet.

There seems to be a proportional relationship between the amount of chert and the occurrence of volcanic rocks. Uncommonly thick units of chert have been reported to be associated with volcanic rocks to the north (Hershey, 1906, p. 59). This also seems to be the case here, however the genetic relationship between the Beegum Gorge-Tedoc road cherts and the various metavolcanic units is not known except that the volcanism may have contributed some of the necessary silica for chert formation.

Because of their paleontologic importance, limestones in the western Paleozoic and Triassic belt have received a considerable degree of attention. In this area, limestones occur as massive outcrops, as interbeds in the metasedimentary sequence, and as small fault-bounded bodies in shear zones. Overall, limestones are one of the minor lithologic types in the basement complex. The large, massive outcrops (as in sections 22 and 34, T. 29 N., R. 9 W.) are very light gray in color and are made up of recrystallized organic detrital limestone (biocalcarenite) that has been cataclastically deformed. The organic origin is ascribed on the basis of probable calcareous algal fragments seen in thin-section. Such algal occurrences have been noted in the nearby Whiterock locality in the northeastern portion of Dubakella Mountain quadrangle (Silberling and Irwin, 1962, p. 861). Using Friedman's method (1959, p. 89) of organic stains for selec-
tively coloring calcium and magnesium, stained surfaces of limestone from section 22 failed to show any evidence of dolomite.

The limestone which occurs with the chert interbeds in Beegum Gorge is of a different nature than the massive crystalline bodies. Here, the limestones are very light gray and exhibit an apparent bedding on an interval of one inch to two feet. The small scale bedding is actually defined by the bands of segregated chert. The gross attitude of the limestones can be determined only by their relation to the surrounding argillite units. Throughout the entire area most of the limestone bands tend to parallel the trend of the basement complex, that is approximately northwest and southeast. It is the conclusion of this writer that metamorphism must have erased any fossil remains in these interbedded limestones, if ever present, because thin-section study failed to reveal any organic structures. However, unlike the massive material, these are considerably less fractured.

There are several limited occurrences of marble-like material exposed in the shear zones of various faults in the basement complex and also in a single structurally confused area along Highway 36 between Beegum and Platina (SW 1/4, section 15, T. 29 N., R. 9 W.). In all cases these carbonate rocks are intensely folded and sheared with the surrounding units to such a degree that it is often difficult to distinguish them in the field. Such exposures are usually associated with small mineral
springs and limited amounts of recent precipitates such as epsomite.

**Volcanic Rocks**

All of the rocks within this area which had an originally basic volcanic origin, and whose original structures and textures seem to have largely been destroyed by metamorphism, are grouped under the term of aphanitic greenstones. These are characterized by their dark green-gray color and pre-dominance of the chlorite-hornblende-epidote mineral suite. Irwin (1960, p. 23) uses the term greenstones to include some intrusive units, however it will be restricted here to those rocks which are probably interbedded with metasedimentary units and therefore of an extrusive origin. Large area exposures were mapped as metavolcanic (Plate 1) when such units contain originally volcanic rocks well in excess of their metasedimentary interbeds.

In the southern-most exposure (sections 20 and 21, T. 28 N., R. 9 W.) of the largest metavolcanic unit the greenstones, which are exposed in road cuts, retain some of their original texture. Here, a light green and very dense groundmass contains large pheocrysts (up to one-fourth inch) of relict hornblende and small subhedral bodies of kaolinite after feldspar. The feldspar relics define the rough foliation of the unit.

The greenstones of this area are similar to those of other
portions of the western Paleozoic and Triassic belt. A few outcrops contain rocks with relict phenocrysts of mafic minerals (pyroxene?) as described by Davis et al. (1965, p. 949) in the metavolcanic rocks of the Russian Peak area, southwestern Siskiyou County. Nowhere are there any of the calcite or quartz filled vesicles, however, which are in the Russian Peak volcanic rocks.

The microlites of the greenstone groundmass seem to be mostly very sodic plagioclase in the albite range. Fibrous green hornblende and brown biotite make up the bulk of the grains with chlorite and epidote being important minor constituents. Such an association points to a degree of metamorphism in the quartz-albite-epidote-biotite subfacies of the greenschist facies (Turner and Verhoogen, 1960, p. 537). The notably darker color of the greenstones near the basic intrusions may be attributed to an increase in biotite as a result of contact metamorphism.

Not all of the extrusive igneous rocks in this area are greenstones. Of particular interest is the large single exposure of only slightly altered andesite and diabase in upper Nelson Creek (S 1/2, section 34, T. 29 N., R. 9 W. and N 1/2 section 3, T. 28 N.). The andesite is particularly light in tone with a finely porphyritic texture. Although no large scale flow or bedding features were observed, on the hand specimen scale the dark minerals tend to be aligned in a subparallel manner. The
only significant metamorphism which has affected the Nelson Creek andesitic rocks is a partial alteration of hypersthene to biotite.

Poor exposures and somewhat ambiguous terminology make correlation of the volcanic units difficult over large areas. The greenstones which were described by Hinds (1932, p. 393) and referred to his Chancelulla Peak Formation (see Figure 4) seem generally comparable to those in this area. Less altered andesites have also been pointed out in other parts of the western Paleozoic and Triassic belt (Diller, 1903; Irwin, 1960), however, they have not been referred to any specific lithologic division. The total thickness of the metasedimentary and volcanic units in the belt is indeterminable. Because of structural complexity, poor exposures, and local unconformities, no attempt was made to measure any sections within this area. However, in Beegum Gorge alone, the metasedimentary sequence may exceed 9,000 feet in stratigraphic thickness.

**Intrusive Igneous Rocks**

There are two significant occurrences of basic intrusive material in this area, both being in close proximity to one another. The most noticeable in its exposure is referred to as the Walker Point stock in sections 8, 9, and 17, T. 28 N., R. 9 W. This is made up mostly of coarsely crystalline, dark green gabbro with subordinate amounts of calcic diorite. A number of non-oriented, white aplite veinlets cut across this stock. At
least the major portion of the Walker Point stock outcrop is easy to recognize because of its resistant cliffs. The other important basic intrusion is located east of the Tedoc road, having a linear outcrop which is exposed from Old Man Springs Creek on the north to the ridge between Bear Gulch and Basin Gulch (from section 15 to 23). Actually, the linear arrangement may be more apparent than real because the entire east side of the gabbro is unconformably overlain by conglomerates of the Sacramento Valley succession. This occurrence is petrologically similar to the Walker Point gabbro except that this eastern exposure has no diorite in association with it.

There are two smaller outcrops of the same basic material located between the two larger occurrences. The small, irregular Coyote Gulch exposure (W 1/2, section 15) is exactly like the Old Man Springs-Bear Gulch gabbro except for a higher degree of iron alteration. A minor fault bounded segment (center, section 16) appears to have originated from the larger body to the east, however, it is of a slightly more dioritic composition.

The weathered outcrop color of all the intrusives is unusually light. This is due to plagioclase hydration and is probably the reason for Irwin (1960) and Strand (1962) mapping the Walker Point stock as being of a granitic composition. Actually, the freshly broken surfaces are very dark, even in the case of the diorites.
The bulk of the intrusive rocks is made up of dark green holocrystalline, medium and coarse-grained gabbro. The major minerals include clinopyroxene (hypersthene?), calcic plagioclase, and olivine. The minerals themselves appear to have undergone only a slight amount of deuteric alteration. They may not have been subjected to the same greenschist facies metamorphism which influenced the surrounding basement units. Occurring in a few places within some of the gabbro are small patches of diorite. The contacts between the two are very gradational and the diorite is of a basic nature. Such evidence indicates a common genetic relation between the two. Indeed, the composition of the diorite is similar to the gabbro except for there being more hornblende and biotite in the diorite. There is also a slightly higher plagioclase content in the diorite which is responsible for its lighter color.

Of particular interest, and of possible economic importance, is the contact alteration which adjoins portions of these intrusions. Contact metamorphism which accompanied intrusion altered the surrounding units to produce several magnetite rich deposits. The greatest concentration of this magnetite occurs in the center of section 8 and in the western portion of section 15 (T. 28 N., R. 9 W.). Here, the iron content is high enough to severely deflect a compass needle. On these two locations mining claims have been made. Other alterations include the
pyritization of the metaconglomerates in the northwesternmost part of section 17.

These basic rocks are considered to be truly intrusive (rather than "granitized" material) for the following reasons:
1) the unique occurrence of these rocks; they are not common in the surrounding area, 2) the contact between the gabbro and the wall rock is very sharp wherever it is exposed; within the diorite there are several pyritized metasedimentary xenoliths and a pendant with well defined margins, 3) the igneous rocks are cross-cut with small aplite dikes which do not extend into the metamorphic units, 4) there is a marked aureole of magnetite mineralization around the gabbro; such does not occur elsewhere in the area, 5) the structure of the basement units becomes increasingly more complex near the margins of the gabbro, and 6) there are basic dikes of a known discordant intrusive nature nearby.

The exact size of these igneous bodies is difficult to ascertain. The surficial exposure of the Walker Point stock is less than two square miles, the western margin being just west of where Plate 1 ends. A portion of this exposure is unconformably overlain by conglomerates of the Sacramento Valley succession, so its eastern limit cannot be determined. The same is true for the Old Man Springs-Bear Gulch gabbro. The igneous rocks cannot extend too far to the east under the sedimentary
cover or they would have shown up as a larger magnetic anomaly on
the aeromagnetic surveys which have been conducted in this region
(Irwin and Bath, 1962, Figure 25.1). A magnetic profile across
this area shows only a moderate high (600 gammas) which can be
attributed to the exposed gabbro and the nearby ultramafic bodies.

The depth and temperature of intrusion are even more dif-
ficult to interpret. The emplacement environment, however, is
tentatively assigned to the mesozone (Buddington, 1959) for the
following reasons: 1) the surrounding country rock is character-
ized as being stable within the greenschist facies (upper limit
of seven to 10 kilometers), 2) there is no wall rock granitiza-
tion, 3) the intrusive contacts are sharp wherever they are
exposed, 4) there is at least a partly developed contact meta-
morphic aureole, 5) moderate deformation of the country rock
extends only a short distance from the intrusion, 6) indications
are that emplacement was by magnetic stopping and forceful injec-
tion, 7) there is a possible relationship with known mesozonal
batholiths in the Coast Ranges, Klamath Mountains, and Sierra
Nevada, and 8) these injections appear to be late tectonic in
their emplacement age relation to the regional history. All of
these features fit Buddington's definition of a mesozonal environ-
ment of intrusion.

The intrusive units in and around this area have not been
described by any previous writers. The Walker Point gabbroic
stock was mapped as granite by Irwin (1960, Plate 1) and has been incorrectly placed at least four miles to the northwest of its true location. Strand (1962), on the Redding sheet of the geologic map of California, shows the correct location for the stock but also lists it as granitic. Strand's inclusion of a small body of "basic intrusive" north of Wells Creek only approximates a portion of the real exposure there.

The intrusive units in this area are all thought to be of about the same age and are all probably related to the Nevadan orogenic epoch of Kimmeridgian to Tithonian age. Most authors (as Kinkel et al., 1956, p. 195; Curtis et al., 1958, p. 6) feel that such emplacements followed the folding stage and that they therefore represent a terminal feature of the orogenic cycle.

**Ultramafic Rocks**

The limited exposure of serpentine and peridotite in the map area is not typical of the amount of ultramafic rocks in the southern Klamath Mountains. Only the southernmost portion of a very large northeast-southwest trending body is exposed in parts of sections 20, 21, 27, 28, and 29, T. 28 N., R. 9 W. Some small patches of serpentine also appear in shear zones throughout much of the basement complex. Although serpentine detritus is common in many of the younger sedimentary units elsewhere, including the Lower Cretaceous, none has been found in this area in spite of intensive search. This fact seems unusual because the basal
conglomerate almost directly overlies the serpentine in section 27 and contains clasts of rocks similar to those in the nearby basement.

There appears to be a difference, both in petrology and genesis, between the ultramafic rocks of the various provinces. For example, Dondanville (1958, p. 9) reported that the altered peridotite of northwestern Glenn County (northern Coast Ranges) contains harzburgite as the most common rock. Rynearson (1944, p. 198) examined the serpentines of other portions of the Coast Ranges and stated that chrysotile is a very common constituent in the form of veinlets. In the Klamath Mountains north of Weaverville, Trinity County, the ultramafic material is almost all antigorite with minor amounts of dunite (Davis et al., 1965, p. 960). The large ultramafic sheet of the northern part of the Klamath Mountains is also similar in petrology (Irwin and Lipman, 1962, p. 20). Irwin (1960, p. 57) reported that the overall Klamath Mountains' ultramafic rocks are mostly composed of peridotites and related antigorite serpentine with no chrysotile. From such observances it is necessary to relate the ultramafic occurrences of this area to the ones of the Klamath Mountains province. The serpentine from the southwest portion of this map area and the Dutchman Gulch peridotite bear far less resemblance, except in their chromite deposits, to the ultramafic exposures in the northern Coast Ranges.
The Tedoc serpentine exposure (characterized by the serpentine of Tedoc Mountain, NW 1/4, section 29, T. 28 N., R. 9 W.) is composed almost entirely of peridotite derived antigorite. Study of this is difficult because of the highly sheared nature of the body, however, it seems to grade into less altered peridotite to the west (section 20). This, like the Dutchman Gulch peridotite, is definitely of the Alpine type. Antigorite is the major constituent, probably making up over ninety percent of the altered portion of the body. Included with this are minor amounts of dunite and pyroxene (enstatite?) which occur as thin, intermittent stringers parallel to the general serpentine foliation. A few remnant olivine grains, mostly replaced by radiating antigorite flakes, indicate that the original rock was peridotite. This body contains no chrysotile; however, some enstatite appears to have been altered to fibrous talc (basite?).

The peridotite body south of Dutchman Gulch is definitely less altered than the Tedoc serpentine and is structurally less complex. It is very dark green in color and is coarsely crystalline. These two features make it very difficult to separate from the gabbro which intrudes it. Although all of the olivine in this peridotite is slightly altered to antigorite, much of this alteration has taken place only on the individual crystal margins. Enstatite may be as high as ten percent of the total composition, but there is not enough of this orthopyroxene to classify the
rock as harzburgite (as many of the Coast Range peridotites). The small amounts of clinopyroxene present are diopside or augite.

Both the serpentine and the peridotite have a high magnetic susceptibility as indicated by strong local compass deflections and the 600 gamma magnetic anomaly of an aeromagnetic survey (Irwin and Bath, 1962). This magnetic property probably stems from a combination of several serpentine components, including free magnetite and other ores of iron, chromite, and the high iron content of the olivine in the peridotite.

Accessory chromite is not common in this particular area although it is common only a mile to the south in sections 27 and 28, T. 28 N., R. 9 W. The geology of similar chromite deposits has been reviewed by Rynearson (1944). In the southwestern portion of the map area, chromite is present only as disseminated ore, while along the peridotite-gabbro contact in Dutchman Gulch there are a few small chromite veinlets. The disseminated chromite must have formed with magmatic cooling because it occurs in some of the olivine and pyroxene grains. The origin of the Dutchman Gulch ore is open to question, but may be of a contact hydrothermal nature.

The ultramafic intrusion probably preceded the gabbroic intrusion because the latter seems to intrude the former. The middle Kimmeridgian age of emplacement is based on the works of other authors in the region (particularly Davis et al., 1965) as
well as on the local field relations. Basic igneous rocks and ultramafic intrusions both occur in close proximity to one another throughout the belt. In all documented cases the ultramafic emplacement took place first.

Because of the high degree of alteration, an analysis of the structure appears to be the best method for investigating the nature of the ultramafic emplacement. On a regional scale Irwin and Lipman (1962) have shown that the large ultramafic trend through the Klamath Mountains is part of a once continuous, subhorizontal sheet which was intruded or thrust along a major unconformity. Such an idea is supported by the work of Davis et al., (1965) in the Trinity Alps intrusion. Actually, it is the fundamental nature of the intrusive material which is in question. The material may have been emplaced in a molten state or possibly "cold", in a plastic manner. Interpretation is complicated by the fact that the body may have undergone structural dislocation after, or because of, intrusion and serpentinization.

Although the high magnetic property of the ultramafic material in this area has prevented any small-scale analysis (by compass orientation), the following are several structural observations of the main serpentinite body in the southwest portion of the map area: 1) joints are much more common in the serpentinite than in the surrounding metamorphic rocks; such joints are also more complex in the ultramafics, 2) the faulted lobate
extremities of the serpentine in sections 22 and 27, T. 28 N., R. 9 W. are structurally most complex, 3) toward the margins many of the joints are offset by small faults, indicative of late or repeated movement, 4) the serpentine-country rock contact is always sheared wherever exposed, 5) most joint and fracture sets strike northeast-southwest in the middle of a body (the grain of the basement has this same trend); these become disoriented near the margins, 6) country rock joints often parallel the contact, 7) the elongation of the whole ultramafic body tends to parallel the structural grain of the belt, 8) some faulting has affected both the serpentine and the surrounding units, 9) in all cases the serpentine appears to have been more responsive to local stress variations than the surrounding rocks (particularly in section 27), 10) to the south, chromite veinlets parallel the major serpentine joint sets, and 11) the antigorite of the contact zone is exemplified by a nontextured nature and a lack of any relict olivine.

The observations suggest to the writer that, after the solidification of the peridotite magma and its serpentinization, the ultramafic body has undergone at least minor dislocation. The peridotite intrusion was probably controlled by a basement lineament (i.e., a major unconformity or fault zone) which accounts for its parallel nature to the structural grain of the basement. The lack of alteration of the basement rocks along
the ultramafic contact indicates that the body has been moved since the peridotite intrusion.

Regional relations suggest that the peridotite magma was intruded during the same general orogenic cycle which produced the gabbro intrusions (Irwin and Lipman, 1962). In this area the peridotite must have preceded the gabbro as indicated by the contact relations in Dutchman Gulch. Serpentinization may have started during intrusion. This alteration did not go to completion as evidenced by the exposed peridotite which is only partly metamorphosed. The post-cooling dislocation was caused by the same deformation which affected the rest of the basement complex during the Late Jurassic.
CHAPTER III

SEDIMENTARY SUCCESSION

General Relations

The stratified rocks along the west side and the northwestern portion of the Sacramento Valley are of considerable interest because they form the thickest and possibly the most complete sedimentary section of the Cretaceous System in North America. Within the map area the Lower Cretaceous strata are represented by the Rector Member and part of the Ogo Member of the Budden Canyon Formation. It is probable that some of the basal conglomerate in the southwest belongs to the Late Jurassic Knoxville Formation. These sedimentary units are the dominant rocks of the map area, making up all of the exposures east of the basement complex outcrops and also occurring as outliers on the metamorphic rocks in the northwest portion.

The thick conglomerate unit east of the shale beds (sections 15 to 25, T. 28 N., R. 9 W.) and the basal conglomerate in the central and northern portions of the map area appear to belong definitely to the Rector Member. The conglomerate to the south is massive and very thick and has few structural disturbances. The northern unit, on the other hand, is discontinuous, thin in places, and highly faulted. Although the conglomerate exposed in the southwest is not distinguishable from the Rector Member
on a purely lithologic basis, it has tentatively been referred to the Knoxville Formation of the Northern Coast Ranges.

All of the exposed stratified rocks east of the Rector Member are represented by the Ogo Member. This latter unit is dominated by dark gray, thin-bedded shale with subordinate amounts of interbedded conglomerate, pebbly mudstone, coarse and fine-grained sandstone and siltstone. Up-section from the basal conglomerate no other lithologic types than these are present. In the northern portion of the map area the Ogo Member locally lies directly on the basement complex.

Age and Correlation

Nomenclature Problem. The Upper Jurassic-Lower Cretaceous strata of this region have a confused nomenclature history caused largely from the lack of precise definition of early terminology and the subsequent lack of agreement as to how the early names were to be applied. Lachenbruch (1962, p. 53) has discussed the problems of this confused history. The reader is referred to Popenoe (in: Popenoe et al., 1960, p. 1492) and Chuber (1963) for a complete outline of the historical development of this nomenclature.

Several authors are worthy of mention because their works contribute directly to the rock unit nomenclature of this area. Diller and Stanton (1894) included the Late Mesozoic rocks of the Sacramento Valley into the Shasta-Chico Series and recognized...
Knoxville, Horsetown, and Chico "beds"; he considered the entire section to be Cretaceous in age. Later, Anderson revised their units by referring the Lower Cretaceous strata to the Shasta Series (1933, 1938) and subdivided it into the Horsetown Group (upper part) and the Paskenta Group (lower part). Anderson (1932, 1933) further recognized that the Knoxville of earlier workers was not Cretaceous, but Late Jurassic in age and was separated from the Lower Cretaceous rocks by an unconformity.

Difficulty in agreement on the nomenclature of the Sacramento Valley units has been the result of these and other authors using time, rock, and time-rock terminology on a nonuniform and unagreed upon manner. Modern, more precise lithostratigraphic and biostratigraphic investigations were instigated by Murphy (1954, 1956). Two important changes resulted. First, the terms of Shasta, Paskenta, and Horsetown were redefined as strictly time-stratigraphic units. Murphy's use (1956) of Shasta Series, with its Paskenta and Horsetown Stages, has been retained through to the present. Secondly, based on the first detailed geologic mapping in the Ono quadrangle, the rocks were subdivided into mappable lithologic units, the Rector and Ono Formations. Unfortunately the northern limits of the Knoxville rocks and the southern extent of the Rector-Ono Formations was never treated. After extended mapping, Murphy et al. (1964) found it necessary to revise the original work of Murphy (1956) to make the nomen-
clature more suitable to cover a larger area. This was done by placing the entire Cretaceous succession under the formational name of Budden Canyon. The former Rector Formation was reduced to member rank. The Ono Formation was abandoned. These recent authors still did not, however, define the southern extent of the Budden Canyon Formation or indicate its relation to the Knoxville.

At the same time, Peterson (1963, 1964), in a study of regional Cretaceous stratigraphy, was able to define a number of unconformity bounded "sequences" of significant extent. Although their discovery does not alter the validity of the present nomenclature, it is important because they are contrary to the long-held belief that the Cretaceous of the Sacramento Valley represented an unbroken history of marine sedimentation. Peterson's Sequence A is represented in this area by rocks of the Neocomian Rector and Ogo Members.

**Knoxville-Budden Canyon Relations.** Anderson (1933, 1945) outlined the lithologic and faunal criteria necessary to separate the Upper Jurassic units from the Lower Cretaceous units along the west side of the Sacramento Valley. Since that time, numerous authors have extended the break northward. The problem lies not in the identification of the Budden Canyon material to the north or the Knoxville material to the south, but rather in the nature, and indeed the location, of the contact between the two in the northwestern portion of Tehama County. Numerous authors have
placed this contact, with varying degrees of question, in several places. For example, Irwin (1960, Plate 1) shows it extending up to Beegum Point in this area and including several outliers of the Rector conglomerate in his "Knoxville Group". Lachenbruch (1962, Plate 2) places the northern terminus of the Knoxville in the Wells Creek Peak area in the northeastern portion of the Yolla Bolly quadrangle (see Figure 2), immediately southwest of this area. Some other authors have placed the contact further south, as Strand (1962) did in terminating the Knoxville Group at Elder Creek near Lowrey. Curtis et al. (1958, Figure 2) have extended it northeast of Plata and into the Ono quadrangle. Unfortunately, all of the previous authors have neglected to state the basis on which these contacts have been mapped. Most of the difficulty stems from the lack of detailed geologic studies in the critical contact area (Chancelulla Peak, Yolla Bolly, and Colyear Springs quadrangles; see Figure 2), the almost complete lack of fossils within the succession, and the inability to separate much of the Knoxville Formation from the Budden Canyon Formation on purely lithologic basis. Work in progress by Jones and Bailey of the U. S. Geological Survey in the Colyear Springs quadrangle indicates that Upper Jurassic fossils occur in the northern portion of that area. Based on this data, Q. A. Aune of the California Division of Mines has continued the contact into the Chancelulla Peak quadrangle (California Division
Such information indicates that the upper contact of the Knoxville Formation does extend into this map area. However, because of the lack of any fossil control and the similarity of lithologic characteristics of the Knoxville and Rector (basal Budden Canyon Formation) conglomerates, the exact location of the contact is open to question. Despite an intensive search, the only distinct evidence for a break in the mass of conglomeratic material south of Beegum Peak is a single shale unit which strikes parallel to the regional trend (Plate 1). This shale unit thins from a maximum of five hundred feet in section 25 (T. 28 N., R. 9 W.) to an apparent lens-out somewhere in SW 1/4, section 9. No other such shale interbeds in the conglomerate occur in this area. This shale unit is presented in this report as an informal, upper member of the Knoxville Formation. The conglomerates west of this shale unit are thought to belong to the Knoxville Formation while those to the east are referred to the Rector Member of the Budden Canyon Formation. The sedimentary outliers in sections 20, 29, and 32, T. 28 N., R. 9 W. are regarded as the Budden Canyon Formation.

**Map Units.** Table I outlines the lithostratigraphic units, and their assigned ages, which have been mapped for this study. The ages of the members of the Budden Canyon Formation area are
based on Murphy's (1956) work in the equivalent units in the Ono quadrangle and by the recent ammonite correlations by Imlay (1960, p. 167). There are numerous mappable units within the Ogo Member which exhibit discontinuous outcrop pattern, but which follow the structural trend of the main member. These are made up of resistant, ridge forming detritus of a considerably coarser texture than the usual shale.

**TABLE I**

MAPPED SEDIMENTARY UNITS, SOUTHEASTERN PORTION, CHANCELLORLA PEAK QUADRANGLE

<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Map Symbol</th>
<th>Dominate Rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Cretaceous - Budden Canyon Formation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ogo Member</td>
<td>Kbo</td>
<td>-</td>
<td>Shale with conglomerate and sandstone</td>
</tr>
<tr>
<td>Rector Member</td>
<td>Kbr</td>
<td>-</td>
<td>Conglomerate</td>
</tr>
<tr>
<td>Upper Jurassic - Knoxville Formation (?)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shale member</td>
<td>Jks</td>
<td>-</td>
<td>Shale</td>
</tr>
<tr>
<td>Conglomerate member</td>
<td>Jkc</td>
<td>-</td>
<td>Conglomerate</td>
</tr>
</tbody>
</table>

**Knoxville Formation**

**Basal Unconformity.** The contact at the base of the Knoxville Formation can best be described as a nonconformity where stratified rocks rest unconformably upon intrusive igneous and metamorphic rocks. There is no doubt that this basic contact is unconformable. Evidence includes: 1) indications of a marked
change in regimen with metamorphic and igneous rocks below and sedimentary rocks above, 2) no contact metamorphism can be observed in the sedimentary rocks where they are in contact with the igneous intrusions, 3) structurally, there is a significant angular discordance between the basement complex and the sedimentary cover, 4) there exists erosional relief on the basement surface, 5) there is a significant faunal break between the youngest known metamorphic units and the oldest Knoxville rocks to the south of this area, and 6) the basal conglomerate contains reworked basement material.

This unconformity was produced during an erosional episode of the Nevadan orogeny which occurred during the Late Jurassic. In this area the break is indicated by sediments on crystalline and metamorphic rocks. It probably extends southward to the Tomhead Mountain area (central Yolla Bolly quadrangle) which is the southern terminus of the Klamath Mountains complex. Unfortunately, owing to the poor exposures in this area, the contact between the basal conglomerate and the units of the basement is difficult to observe. The best exposures found are in the Wells Creek area (section 26, T. 28 N., R. 9 W.) and to a lesser extent, the slope in NE 1/4 section 16. The actual contact is characterized by gentle irregularities in the basement surface. Minor amounts of water often seep along the entire exposure of the contact. In no case is there any evidence for movement of a
decollement or thrusting nature.

Conglomerate Member, Lithostratigraphic Description. The sediments of the Knoxville Formation in this area have been divided into two informal mappable units; the conglomerate member and the shale member. The conglomerate member is by far the most conspicuous and, although conglomerates are the most common lithic type, it also contains numerous sandstone stringers and lenses. Specifically, the basal conglomerate member is made up of clasts which are in the pebble to boulder size range with the smaller clasts being the most common. All of the included clasts are rounded to subrounded in shape and tend to be size graded only in the crudest manner. By Pettijohn's classification (1957, p. 255) they are epiclastic, extra-formational, polymictic ortho-conglomerates. That is, the clasts were derived from outside the site of deposition and are made up of mixed rocktypes. This conglomerate member is characterized by a coarse-grained matrix of lithic sandstone, the individual grains of which are subangular. On freshly broken surfaces the color of all the basal conglomerates is a very dark gray-blue-green. Locally, the color may appear lighter due to the inclusion of large, light quartzite clasts. Oxidation of a minor ferruginous cementing material produces a reddish-brown weathered outcrop.

No attempt was made to conduct a systematic study of the clasts in this area. However, field observations indicate that
there is no evident change in clast composition along strike, throughout the stratigraphic section, or between the Knoxville Formation and the overlying Rector Member. Qualitatively, in order of decreasing abundance, these clasts include: chert, chert microbreccia, fine-grained greenstone, quartzite, plagioclase porphyry (light), porphyritic andesite (dark), quartz, and argillite. These clasts typically are pebbles which average one-half to one and one-half inches in their longest dimension and are in contact with other clasts at least at one point. The majority of the pebbles are roughly elongate and tend to form a crude lineation by parallel alignment of the axis of elongation; no imbrication was noted. For the larger clasts (up to three feet in diameter) the alignment is even less defined, the elongation being inversely proportional to the size.

The clasts constitute from seventy to eighty percent of the conglomerate units, the remaining material being the coarse, angular lithic graywacke matrix. The matrix and the clasts are very well indurated and are bonded with a material composed mostly of silt and clay sized particles with very minor amounts of ferruginous and calcareous minerals. The sandstone lenses which occur in the member are nowhere well exposed, but appear to be very similar to those which are described for the Rector Member of the Budden Canyon Formation.

Bedding attitudes in all of the basal conglomerate are
difficult to obtain because of the lack of any well defined planes. Depositional surfaces can best be seen on weathered outcrops where differential erosion has made the densely conglomeratic horizons stand out from the ones with a higher percentage of matrix. Such attitudes can be less readily seen in the crude size sorting of the different horizons. Because the sandstone lenses are parallel with the conglomerate bedding their attitudes can be used whenever found to represent the main body.

In general, the bedding of the member is very thick to massive. Exposures are too poor to draw many definite conclusions regarding the subsurface extent of these conglomerates, however, their mass suggests that they may be more continuous in depth than the thinner, intermittent Rector Member conglomerates to the north. Surficially, the conglomerate member extends from Walker Point southward into the Yolla Bolly quadrangle. It ranges in thickness from approximately 210 feet to over 3250 feet. The bedding attitudes seem to parallel those of the overlying shale member and Rector Member. Nowhere in this area are there exposed any of the load casts which have been described in the conglomerates of the Upper Jurassic and Lower Cretaceous of Glenn County (Dondanville, 1958, p. 19.) All of the basal conglomerates are completely devoid of the sedimentary structures which are so common in the interbedded conglomerates of the Ogo Member.
Shale Member, Lithostratigraphic Description. As previously stated, the separation of the Knoxville Formation from the Rector Member has been tentatively made in this area on the occurrence of a single shale unit within the thick conglomerate section of the southwestern portion. This shale is lithologically similar to the shale of the Ogo Member except that it is somewhat less concretionary. Those shaly concretions which do occur have a coarse sand grain fraction which is missing from the Ogo concretions. Some of the concretions in this unit are formed around fragments of shale. The unit as a whole consists of dark gray, thinly laminated to thinly bedded (one-half to three inches), highly fissile shale. The upper and lower contacts with the conglomerates are obscured.

There is no direct evidence to suggest with which of the two conglomerate units this shale unit is associated. To the north this shale seems to thin gradually until it completely disappears in SW 1/4 section 9, T. 28 N., R. 9 W. This may indicate partial removal by erosion, and therefore an association with the lower conglomerate member. This could possibly be a depositional thinning, however, particularly when a northern thinning appears to be the trend for many of the clastic units in this region. The final reference to the shale member of the Knoxville Formation by this writer was based on the fact that no shale has ever been found in the Rector Member while minor amounts have been reported
in the Knoxville of the Paskenta area (Harrington, 1942).

The bedding planes of the shale member have attitudes similar to the surrounding units, indicating that little structural deformation took place immediately before or after the deposition of this member. The shale ranges in thickness from about two hundred to seven hundred feet south of the Pattymocus fault and completely disappears north of that fault.

**Budden Canyon Formation**

**Basal Unconformity.** In the northern portion of the map area the sub-Budden Canyon unconformity is represented by the sediments of the Rector and Ogo Members resting on the metasedimentary rocks of the Applegate Formation with a marked angular discordance. Between the area of Beegum Peak and Walker Point this unconformity is represented by the contact between the shale member of the Knoxville Formation and the Rector Member of the Budden Canyon Formation.

Like the basal Knoxville unconformity, the contact at the base of the Budden Canyon Formation is marked by minor irregularities in the basement surface. The best exposures of this unconformity were found in the stream bed of Beegum Creek along the Highway 36 road cuts in the vicinity of Beegum. In areas such as these the contact actually appears to be gradational in some cases. However, this is only apparent and can be attributed to the fact that locally the conglomerates contain clasts of the
same material which they overlie. This is particularly noticeable in the case of the light green quartzite outcrop just east of the new Beegum bridge.

**Rector Member, Lithostratigraphic Description.** Because the Rector Member of the Budden Canyon Formation is lithologically very similar to the conglomerate member of the Knoxville Formation, much of what has been previously discussed directly applies here. The clast composition and texture, as well as the nature of the matrix and cementing material, appear to be very nearly the same. Although the Rector Member probably contains some re-worked Knoxville clasts, there is no notable reduction in clast size.

The graywacke sandstone lenses and beds which appear here are slightly more continuous than those of the Knoxville Formation, but are otherwise similar. They are relatively few and are often conglomeratic with pebbles of basement or Knoxville rocks. Such units are always parallel in attitude with the conglomerate bedding and locally have gradational boundaries with the main unit. The sandstone in these lenses is composed of a somewhat finer-grained material than the matrix of the conglomerate and the grains are better rounded. These medium-grained sandstones are not graded, but are much better sorted than the matrix of the conglomerate. Petrographically, they are classified as a subgraywacke or lithic sandstone (Pettijohn, 1957, Table 48)
because of their higher quartz content than the usual Lower Cre-
taceous graywackes. Current erosion features occur at the base of a few of the sandstone lenses. These are indicated by irreg-
ularities in the surface of the main conglomerate which have been filled with sandstone. Such erosion is best interpreted as being caused by the channeling process of bottom currents, per-
haps of a long-shore nature.

Surficially, the conglomerate unit is most often seen as subdued, knobby outcrops with large erosional pits and crevices. The crevices follow joint patterns in the rock while the pits are controlled by solution of the matrix along the original planes of deposition. A notable exception to the lack of outstanding con-
glomerate outcrops is Beegum Peak. Here, conglomerate of the Rector Member forms vertical cliffs on an isolated topographic high with more than 650 feet of local relief.

To the north, the Rector Member is extremely variable in thickness, ranging up to a maximum of nine hundred feet in sec-
tion 27, T. 29 N., R. 9 W. The average thickness, where exposed, is probably 150 to 250 feet. The northern Rector Member was probably deposited in basement lows (Murphy et al., 1964). Uplift by faulting and subsequent removal of portions of these limited wedges accounts for much of the present intermittent nature of these conglomerate units. South of Beegum Peak, where the Rector Member has overstepped the Knoxville Formation, the
Lower Cretaceous conglomerates become very thick. The southern portion of the Rector Member may be as thick as 3,000 feet, however, the generally poor exposure of this unit may mask important structural influences.

**Rector-Ogo Relations.** The Ogo Member (Murphy et al., 1964, p. 499) consists of the uppermost portion of the old Rector Formation and the lower part of the Ono Formation (Murphy, 1965). It varies greatly in its lithic content in comparison to the Rector Member. Because, however, the physical properties of the Rector and Ogo Members do not differ as greatly as do the metamorphic and sedimentary rocks, the contact between the two members is less well defined than the basal unconformity. Like the basement contact, the Rector-Ogo boundary is best exposed around the Beegum area, particularly in the road cuts of Highway 36.

The contact itself appears to have been subjected to only slight erosion and has no notable relief on its surface. In the Ono area, the contact is gradational from the uppermost Rector Member conglomerate to the granule sandstone, siltstone, and shale of the Ogo Member, however, such a relation is not usually found in this area. In all cases here is a distinct break between the two members; the contact usually is a contrast of boulder or pebble conglomerate and shale. In a few places there is a variably thick (eight inches to three feet), lithic or feldspathic graywacke zone on top of the conglomerate. It is possible that
the places in the northern portion of the map area where the Ogo Member locally rests directly on the metamorphic basement represent completely eroded basal conglomerate. Probably, however, the Rector conglomerate was not deposited in a blanket manner.

Ogo Member, Lithostratigraphic Description. Over eighty percent of the Ogo Member which is exposed in this area is made up of shale. Although the silty component of the shale varies from unit to unit the overall lithic type is remarkably uniform. The terminology which is employed in this thesis to relate these very fine-grained sedimentary rocks is that of Pettijohn (1957, p. 341) where shale is defined as a laminated or fissile, indurated claystone or mudstone. As a whole, the shale in this area can be described as being dark gray, hard, variably silty, and partly calcareous with a conchoidal splintery fracture in places and laminations and fissility parallel to the planes of bedding. The shale laminations and bedding range in thickness from less than one-eighth of an inch to about one and one-half inches. Limestone concretionary beds amount to less than two percent of the entire unit and are spaced rather regularly throughout the shale as four to eight inch thick beds at an approximate ten to twenty-five foot stratigraphic spacing.

The most notable feature of the shale units is the high degree of lamination development and the fissility, for even the thickest bed has easy parting along many parallel planes. Along
with the uniform parting property of the shale is its dark color which lightens only in the concretionary layers because of the high carbonate content. Although the concretionary beds have a high calcium carbonate content (measured up to fourteen percent) the same material is almost completely lacking in the rest of the shale units. There are, however, numerous fractures which are filled with secondary crystalline calcite ranging in thickness from one-eighth to two inches. In all cases the calcite fillings are discordant to the planes of bedding and fissility.

When viewing the Ogo Member exposure as a whole, the non-shale lithic types amount to less than twenty percent of the total section. These units are very important, however, for they provide the evidence for much of the interpretation of the geologic history of the Budden Canyon Formation. The combination and arrangement of shale and graywacke alternations with the less common conglomerate, sandstones, and siltstones seems to represent an almost typical flysch sequence (Boman, 1962, p. 139). Some of these assemblages strongly resemble deposits which have been interpreted as turbidites.

The coarser-grained rocks occur in the shale section in two main ways. First, as rather isolated six inch to two foot thick, medium to very coarse-grained graywacke beds throughout the shale section. Second, as related beds of conglomerate, sandstone, and siltstone. This latter type is the assemblage
which contains certain turbidite characteristics. The shale which occurs above and below both types of the coarser material appears to be the same.

Petrographically, the graywacke beds which occur isolated in the shale section have more in common with the matrix of the Rector Member conglomerate than with the sandstones of the coarse clastic interbeds. That is, they are a feldspathic to lithic graywacke (Pettijohn, 1957, Table 48) in which the feldspar content and the amount of lithic fragments are about the same and in which the detrital matrix exceeds fifteen percent of the total rock. Of the feldspar minerals the potassium variety is a minor amount of the total. The rocks of these beds are almost barren of any chemical cement and owe their high degree of induration to the densely packed, clay-sized material.

The beds in which the graywacke occurs are relatively thin in comparison to the more complete conglomerate-sandstone-siltstone units. Although they are very continuous laterally, these graywacke beds seldom exceed one and one-half feet. Such beds are massive and generally lack any notable internal structures, except for some moderately well developed graded bedding. The contact between these beds and the shale is very abrupt, with no gradation having been found along any of the contacts. Some of the graywacke beds contain small, angular fragments of shale which appear to have been derived from the shale units which are
stratigraphically lower.

This graywacke of the Ogo Member is very dark in color and resembles the Rector Member matrix. Mineralogically, they fit the typical graywacke description with non-potash feldspar and angular lithic fragments. Without exception, the matrix is an aggregate of microcrystalline material, probably feldspar, chlorite, sericite, and a very minor carbonate fraction. The lithic, or rock fragment, fraction of these rocks is dominated by chert, chert microbreccia, and quartzite. The feldspar grains generally belong to the plagioclase group with a wide range of compositions. Being characterized by a somewhat metastable assemblage, these graywackes have undergone some post-diagenic alteration. The original interstitial mud appears to have been rearranged and altered to produce a number of authigenic minerals, probably including some of the feldspar, all of the sericite and chlorite, and some very minor amounts of pyrite.

The remaining coarse clastic materials of the Ogo Member are usually found in close proximity to one another and have been interpreted by this writer as all being genetically related. They include conglomerate, pebbly mudstone, graywacke sandstone, and siltstone, and are referred to collectively in this report as a coarse clastic assemblage. The typical occurrence of these rocks is in the form of a unit with rude graded bedding on a large scale. That is, conglomerate at the base, very coarse to
finer sandstone in the middle, and siltstone or silty shale at the top. Each of these rock types may be in beds of various thickness or may be missing from any single exposure. The total thickness of an assemblage ranges from two feet to over one hundred feet. Even though the different exposures of this mixed association have different amounts of the various rock types and different internal structures and total thickness, their gross relationship to the shale is always the same. That is, a monotonous sequence of dark gray, thinly laminated shale contains a coarse clastic assemblage, the base of which is usually conglomeratic and which contains numerous rip-up clasts of the underlying shale material. This basal contact is marked in many places by load casts and related features with up to eight inches of vertical relief. Sandy and silty lenses in this conglomerate often carry linear current structures as do the siltstones near the top of the assemblage.

The successively finer portions contain such primary structures as graded bedding, groove casts, convolute laminations, cross ripple laminations, ripple marks, and parting lineations. The upper contact, usually between siltstone and shale, is very distinct but is not as sharp as the basal division. The shales on the top and the bottom of the coarse clastic assemblage appear to be exactly the same. On a large scale, the coarse clastics are laterally continuous, but some appear too thin to the south
and most become finer textured in that direction. These units are
the most resistant of the Ogo Member and are therefore important
ridge formers. A number of the more significant traceable coarse
clastic units have been diagrammatically mapped on Plate 1.

The petrology of these rocks is somewhat different from
that of the Ogo Member isolated graywacke beds or the coarser
detritus of the Rector Member and Knoxville conglomerate member.
For example, although chert, chert breccia, and quartzite clasts
dominate both types of conglomerates, the conglomerate of the
coarse clastic interbeds contains a significant number of clasts
of igneous intrusive material of intermediate composition. The
Ogo Member conglomerates are also considerably less indurated,
lighter in color, much better size graded, and contain clasts of
a smaller average size. The clasts are usually rounded and,
although not imbricated, tend to be very well aligned in such a
manner as to produce the effect of bedding within the conglomerate
units. These rocks also contain a great deal more sandstone in
the form of matrix, interbeds, and lenses than the basal conglomerate.

The thickness of the conglomerate in the coarse assemblage
ranges from about one foot to more than ninety-five feet in dif-
ferent areas, but generally tends to be thinner in the southern
portion. A higher percentage of sandy matrix also seems to pre-
vail towards the south. In many places the conglomeratic portion
of an assemblage pinches out to the south or grades laterally in that direction into a coarse-grained sandstone. In the conglomerates of this type there is a general decrease in both the average size and the maximum size of the included clasts to the south.

There are no examples of small scale erosional channeling at the base of the Ogo Member conglomerates, even where streams have exposed the basal contact to a significant extent in several locations. This is in direct contrast to the conglomerates of the Upper Jurassic section in the Paskenta district where channeling has been interpreted as being formed by normal bottom traction currents (Dondanville, 1958, p. 19).

The sandstones of the coarse clastic assemblages occur in the form of fine to very coarse-grained, light gray and tan graywackes. Although rather thick beds of such sandstone are often found to be associated only with siltstone in the shale sequence, they can often be traced laterally to where they are underlain by conglomerates or to where they grade laterally into conglomeratic beds. The total sandstone thickness of any one outcrop may be as great as fifteen feet and may be made up of individual beds which range in thickness from one to five feet. These units very commonly exhibit well defined graded bedding, particularly in the coarser material, and often contain thin interbeds or lenses (one to three inches) of pebbly mudstone, mudstone, or siltstone.

These sandstones have been classified as graywackes (Petti-
John, 1957, p. 316) because of their mineralogical composition. The coarsest sandstone averages grain totals of: lithic fragments (forty to fifty percent), feldspar (all types, fifteen to twenty-five percent), and quartz-chert (thirty to forty percent). The matrix-cementing material is of a very fine-grained argillaceous nature with an unknown composition. The amount of this matrix varies considerably from about twenty-five to forty percent of the entire sample. The composition of the rock fragments are almost all metamorphic in origin and most commonly include microbrecciated chert, quartzite, volcanic, and possibly some plutonic rocks. Texturally, most of the grains are subangular to subrounded.

Considerable interest has been shown in the nature of the various feldspar minerals in the sandstones of the western Sacramento Valley (particularly Dondanville, 1958; Young, 1958; Bailey and Irwin, 1959; Bailey et al., 1964). There appears to be a direct relation between stratigraphic order and potash feldspar content in that the younger sandstones usually contain significantly more than the older ones, usually in the form of orthoclase. Using acid etching and organic dyes, a rapid method of staining the potassium bearing minerals in a rock has been developed (Chayes, 1952). The modified techniques of this method are best outlined by Bailey and Irwin (1959, p. 2802). Nine graywacke samples were collected along Highway 36 from the Budden Canyon Formation in this area and were stained by the writer; the results appear in Table II.
TABLE II

RESULTS OF STAINING FOR K-FELDSPAR CONTENT OF OGO MEMBER SANDSTONES SAMPLED ALONG HIGHWAY 36. REPORTED IN PERCENTAGES OF THE TOTAL GRAINS.

<table>
<thead>
<tr>
<th>No.</th>
<th>Location*</th>
<th>K-spar %</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Section 17</td>
<td>2.30</td>
<td>From Platina outlier</td>
</tr>
<tr>
<td>2</td>
<td>Section 26</td>
<td>0.20</td>
<td>Above Rector Member</td>
</tr>
<tr>
<td>3</td>
<td>Section 36</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Section 36</td>
<td>0.10</td>
<td>(Numbers 2 to 9 are in increasing stratigraphic order)</td>
</tr>
<tr>
<td>5</td>
<td>Section 31</td>
<td>1.75</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Section 31</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Section 32</td>
<td>2.50</td>
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</tr>
<tr>
<td>8</td>
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<td></td>
</tr>
<tr>
<td>9</td>
<td>Section 3</td>
<td>3.63</td>
<td>Eastern map margin</td>
</tr>
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</table>

* Locations plotted on Plate 1

A review of these data suggests a possible increase in potash feldspar with decreasing age, however, this study is far too limited to support any definite conclusions. The very low content of orthoclase in all of the samples is striking, however. In this area, because the current directions indicated by sedimentary structure analysis (Figure 5) show no radical change in source direction with time, the apparent increase of the orthoclase may be due to progressive exposure of the Klamath Mountains' plutons rather than from different source areas.

Microscopic examination revealed that these sandstone units have undergone only slight post-diagenic change. The most significant alteration has been the chloritization of some of the volcanic fragments and the sericitization of the original mica of
the matrix. Using a technique suggested by Glover (1964), differential focusing through a petrographic microscope equipped with a universal stage showed little interaction between the matrix and the mineral grains.

These sandstones contain numerous convolute laminations and shale rip-up clasts; no concretions were found. The finer grained sandstones, along with the siltstones, did yield significant amounts of petrified plant material.

The siltstones of the coarse clastic assemblages are of particular interest because of their abundance of sedimentary structures and because they contain the few faunal remains which occur in this area. These siltstones make up over fifty percent of the coarse assemblage and also occur as beds with coarse to fine-grained sandstone alone which grade laterally into the complete assemblages. Relatively thick, single beds of siltstone occur in the extreme southeastern portion of the map area. All of the siltstone exhibits an exceptional degree of induration and are very similar to rocks described as "flagstone" elsewhere (Pettijohn, 1957, p. 377). Typically, they are thinly bedded (one inch to one foot), very hard and resistant, and light tan in color. The mineralogy of the siltstones appears to differ significantly from the sandstones in that the finer clastics have a much higher quartz content. The very fine matrix contains abundant mica, clay, and possibly chlorite. Because of its light
color, the micaceous material is probably muscovite.

The most abundant collection of sedimentary structures in the area is contained in the siltstones of the coarse clastic assemblage. These include several types of load features, linear current markings, soft sediment deformation structures, and various current bedding features. Along with these, and often directly associated with them, are large amounts of fossilized floral material, fucoidal markings, and a few faunal remains.

**Sedimentary Structures.** Some amount of extra attention was devoted to the sedimentary structures of the Ogo Member. The various primary structures give partial evidence regarding the nature of the depositional environment. If some of these deposits are turbidites, as much of the evidence suggests, their study has considerably more than local importance. That such deposits form an important part of the geologic record has been noted (Sullwold, 1961) and their importance to the Sacramento Valley petroleum industry has been suggested (Safonov, 1962).

With the exception of a few distorted features which may be best interpreted as submarine slumps, all of the current and deformational primary structures were found in relatively thin conglomerate-sandstone-siltstone units within the Ogo Member. The deformational structures include load casts, certain sole markings, convolute laminations, and various rip-up features, while the current structures include parting lineations, ripple
marks, and cross laminations. The study of such structures elsewhere has gained prominence only recently. The most complete reviews of this subject include the largely descriptive treatment of Potter and Pettijohn (1963) and the numerous interpretative papers edited by Middleton (1965).

Load casts (Kuenen, 1953, p. 104) of various types are common along the base of the Ogo Member conglomerates. These are deformational features which affect the shale material below the conglomerate to a considerable degree in many places. There appears to have taken place an alternating exchange of coarse and fine material between the beds so that there are lobes of shale extending into the conglomerate up to one foot. In a cross-sectional view these casts resemble convolute bedding in that the casts range from small, smooth bulges to highly contorted disturbances. On a plan view, however, the casts are highly localized and do not possess an elongate axis as do most of the convolute laminations. A few of these casts have been shifted after formation, probably in response to paleoslope-current influences (Bouma, 1962; Potter and Pettijohn, 1963).

Groove casts (Shrock, 1948, p. 162) are a current sole marking found at the base of the same units as the load casts. They appear as very elongate, rounded ridges on the underside of sandstone layers which are lying on shale. The relief of these casts ranges from slight protuberances to ridges over one and
one-half inches high. The long trend continues for the entire exposure, sometimes as long as three feet. These structures are not common anywhere in this area; the largest single cluster is located in the Sulphur Gulch-Beegum Creek area (Group 2, Figure 5). Groove casts are regarded as a basal current feature of a turbid flow and parallel to the original current (Bouma, 1962).

In one instance a chert pebble was found in a groove cast, offering a possible instrument of formation as suggested by Stanley (1963, p. 787). In all cases each groove cast is almost parallel to other nearby grooves. Recent experimental work supports the belief that groove casts and certain other sole markings are the product of turbid flow (Dzulynski and Walton, 1962; Dzulynski and Sanders, 1962; Dzulynski, 1965).

The most common of the deformational structures in this area are convolute laminations (originally convolute bedding, Kuenen, 1953). Such convolutions differ from the small gravitational slump structures in that the convolutions are continuous, corrugated folds, often with axes extending the entire exposure of the bed. The convolutions are best developed in the upper portions of the laminated siltstones and fine-grained sandstones. They take the shape of small alternating compressed anticlines and synclines, one to five inches high, with some thickening in the crests and troughs. Post-deformational movement has caused some of these features to assume a common asymmetrical shape,
probably pointing down the original current-slope direction (Potter and Pettijohn, 1963, p. 152). The convolutions are considered to be almost entirely syngenetic and are often found in suggested turbidites of other areas (Bouma, 1962; Dzulynski, 1965; Elliott and Maytum, 1965).

Rip-up clasts and rip-up structures are very common throughout the area and consist of angular shale fragments included in the sandstone and siltstone beds or as locally ripped and discontinuous shale layers. In some localities entire laminated and concretionary beds of shale have been pulled up, overturned, and included in the overlying conglomerate or sandstone at the base of a coarse clastic assemblage. In a few places the rip-up clasts are so abundant as to locally form an intraformational breccia. Few of the rip-up features have preferred orientations.

Ripple marks, small scale cross laminations, and their deformational products all appear to be related in this area. The ripple marks are exposed on the uppermost siltstone beds of the coarse clastic assemblages. They are of a normal current type with very elongate ridges of low amplitude (less than one inch). In exposures immediately below the ripple marks are the cross laminations. These are very small, being on the same scale as the ripple marks, and can be classed as current ripple laminations (Bouma, 1962, p. 137). Both features are known to strike normal to current direction.
Somewhat related to both the load and ripple structures are the flame structures (Potter and Pettijohn, 1963, p. 146) which are small, pointed tongues of shale projecting up into the overlying sandstone. These tongues reach three inches in height and are generally found in groups along strike. In cross-section and in plan view they resemble a linear ripple which has been pulled up and over and streaked out into the above material. Like the convolutions and the ripple marks, they are an elongate feature. They may have resulted from turbid current drag on a layer of clay or by rapid loading of mobile clay material with subsequent movement of the entire mass. Pointing of these tongues probably indicates a direction of paleomovement (Kuenen and Menard, 1952).

Well developed parting lineations occur almost universally on the bedding surfaces of the well indurated, thinly bedded, fine-grained sandstones and siltstones in the area. These features, best seen on weathered surfaces, can be described as a streamlining appearance of fine sand grains on the smooth bedding planes; the name has been suggested by Pettijohn (1957, p. 181) to replace the original "primary current lineations" of Stokes (1947). The observed surface has a coating of one to four grains in thickness with irregularly outlined, but definitely elongated, patches or windows where the coating is missing. Most authors have attributed this patchiness to an imperfection in the origi-
nal cementing material, the elongation resulting from current forces. Previous writers have failed, however, to recognize that in many cases the missing portion of the veneer can be found on the opposite bedding surface. The final solution may be found in a petrofabric analysis of such rocks. In all cases the parting lineations are parallel to the current direction indicated by other oriented primary structures. The partings therefore seem to be a valid indicator of current sense. Dzulynski (1965, p. 208) has pointed out similar features in deep marine turbidites.

Directional measurements taken on the elongate axes of these features, and presented in the form of probable current direction, are shown as rose diagrams on Figure 5. Group 1 measurements were all taken from the area of the Platina outlier in the northwestern portion of the map area. Group 2 and Group 3 readings were collected in the vicinity of the junction of Sulphur Gulch and Beegum Creek and the Whiteman Ranch respectively (sections 20 and 24, T. 29 N., R. 8 W.). Another isolated set of structures were measured in Dry Creek (section 9, T. 28 N., R. 8 W.) and are shown in Group 4. Because of the probable syn-genetic origin of these structures, any post-depositional structural movement would cause a shift from the original orientations. Using a stereographic solution presented by Potter and Pettijohn (1963, p. 259), the tectonic tilt was corrected. Failure of the individual rose diagrams (Figure 5) to be more compact and to
ROSE DIAGRAMS SHOWING RESULTS OF MEASUREMENTS ON OGO MEMBER SEDIMENTARY STRUCTURES, PLOTTED AS INDICATED CURRENT SENSE OR CURRENT DIRECTION. NUMBER OF READINGS IN EACH GROUP IS SHOWN.
more closely follow the trend of the other diagrams can be attributed to one or all of the following reasons: 1) insufficient number of readings, 2) combining measurements from several exposures whose structures have different orientations, 3) local bottom irregularities which may have disrupted the path of the current, 4) inability to obtain accurate measurements in poor exposures, and 5) different clastic assemblages being the result of different currents with slightly divergent paths or different sources.

Unrelated to these structures is a single feature in section 24 along Beegum Creek. Here a subangular boulder, two feet in diameter, of chert breccia is isolated in a section of shale and is in no way associated with any of the other clastic units. The shale laminations under the boulder have been drastically deformed and the layers on top appear to be draped over it. Because such an isolated clast could not have been transported here by turbid or normal current flow, it is most likely the result of some form of rafting. Of all the suggested possibilities (Emery, 1955), rafting by large driftwood or seaweed seems the most reasonable, particularly since there is a large amount of fossilized wood in the area.

**Paleontology**

Fossil remains of fauna are so scarce in this area that, although not particularly studied, they deserve mention. A
single belemnite was found in a pebble conglomerate bed about two hundred feet east of the new Beegum bridge in Beegum Creek (San Diego State College locality 436). In a turbidite-like unit in section 9, T. 28 N., R. 8 W., numerous coiled ammonite imprints were seen and several small brachiopod and pelecypod specimens were collected (S. D. S. C. locality 435). Associated with this latter locality are many fragments of a broad leaf plant, possibly some form of seaweed, preserved by silicification.

In the Platina area a poorly preserved ammonite imprint was found near a large deposit of carbonized wood (S. D. S. C. locality 437). The wood fragments retain their original bark patterns. Unfortunately, in this locality, and elsewhere, the ammonite impressions could not practically be removed for study. Future investigations regarding these ammonites are warranted, however, because they are the most diagnostic fossil for the age of the Lower Cretaceous in the northwestern Sacramento Valley. It is important to recognize that most of these fossils may have been carried and deposited by turbidity currents and therefore do not necessarily represent the indigenous fauna, if any ever existed.

M. A. Murphy is reported to have identified an upper Hauterivian ammonite from a coarse sandstone lens in the Rector Member near the Beegum bridge (G. L. Peterson, San Diego State College, personal communication, 1965). Further search by this
writer in the area yielded only the fragmented belemnite.

In almost every coarse clastic assemblage in this area there is at least one siltstone bed with numerous fucoidal markings on its exposed surface. Various hypotheses have been set forth for the formation of such markings (summarized by Coulter, 1955). It seems most likely that the ones in this area have resulted from the incorporation of sand, silt, and organic material in a gelatinous organism. The chemical by-products of the decomposition of the organism, or its digestive process, have influenced the cementation process during diagenesis, thereby preserving the markings.

**Sedimentary Outliers**

As a whole, the sedimentary rock outliers in the Klamath Mountains have been described only by Irwin (1960, p. 43). Those in this area have been mapped both as Upper Jurassic and as Lower Cretaceous in the past. Anderson (1938, p. 49) reported that the Reading Creek outlier (Weaverville quadrangle) belongs to the Hauterivian Stage. Fossil evidence in the Big Bar outlier (Hyampon quadrangle) indicates that it belongs to the Valanginian Stage (Irwin, 1960). Based on this information, and on the fact that they all lie to the east of the projected Knoxville-Budden Canyon contact, the outliers in this area have been assigned to the Budden Canyon Formation.
About nine hundred feet of shale and minor interbedded sandstone of the Ogo Member are exposed in the mapped portion of the Platina outlier. There are several Rector Member outcrops on the west and east sides of the outlier. The outliers exposed in sections 20, 29, and 30, T. 29 N., R. 9 W. are composed entirely of the Rector Member conglomerates. The southern and eastern sides of the Platina outlier are in fault contact with the basement units. The two smaller conglomerate exposures rest unconformably on the metamorphic rocks. Structurally, the Platina outlier is of interest because it is the only large scale folded feature in the area.

**Sedimentological Interpretation**

Because of the lack of paleontological control in this area, any such interpretation must be based on lithologic evidence and with a comparison to other localities. In this discussion, the writer considers the following facts to be of paramount importance: 1) on top of the unconformable basement contact is a variably thick, massive basal conglomerate containing basement type clasts, 2) a relatively thin shale unit interrupts this conglomerate in the southern portion of the area, 3) the dominant sedimentary product was clay and silt size material, 4) numerous interbeds and tongues of coarse clastic debris are included in the shale, 5) such clastic interbeds are similar to deposits of probable turbidity current origin, 6) most
orientation of sedimentary structures, thinning, and facies changes indicate the coarse detritus was transported grossly from north to south, and 7) there has been little postdepositional change in the sedimentary rocks other than the normal diagenic processes.

The conglomerate member of the Knoxville Formation and the Rector Member of the Budden Canyon Formation were too depositionally limited and lack the necessary sedimentary features to be classed with the environment of the Ogo Member shales and clastic interbeds. The amount of conglomeratic material involved and its stratigraphic arrangement imply a very high energy environment and a possible response to some tectonic or eustatic change. Because of the amount of shale material which was deposited after the conglomerates, it can be assumed that at least part of the tectonic change was depression. Although some uplift may have occurred in the Klamath basement, it need not have been very great. Because the Late Mesozoic sediments are known to have advanced over the basement through time, the conglomerates may indicate the shoreline environment of a transgressing area. Irregularities in the basement surface and in the coastline would be responsible for the variable thickness of the basal conglomerate.

The shale of the Ogo member is the most diagnostic indicator that the sedimentary environment belonged to the quiescent
deep water lithosome. Here, the very fine-grained, thinly laminated, dark, lutaceous material is considered to be a product of pelagic sedimentation in a particle-by-particle manner (Pettijohn, 1957, p. 357; Crook, 1959, p. 336). Numerous other authors have regarded shales like these to be the product of such an environment (including Krumbein, 1947; Shaw, 1965). The uniformly dark gray tone of the shales can be attributed to a high content of carbonaceous material of probable organic origin. Such rocks are indicative of an environment of deposition where organic decay was not particularly active, perhaps as a partly restricted basin. Fine grains of pyrite associated with some concretions point to at least a partially reducing nature for this environment (Dunbar and Rodgers, 1961, p. 202).

The laminations of these rocks must be the result of slight variations in the rate of supply or deposition, or the type of material. They are simply very thin bedding planes in which the differences in silt or carbonate content may locally be seen in the field. The degree to which even the finest of the laminations have been preserved is a measure of the continually placid environment, except where interrupted by comparatively violent clastic invasions. Directly associated with these beddings is the property of highly developed fissility. Gipson (1965) has shown by electron microscopy that it is the particle orientation which is responsible for this in that where the content of organic
material is the greatest, the clay minerals show more preferred alignment, and therefore part more easily.

In direct association with the Ogo Member shale are numerous limy concretionary layers. Because these concretions have caused the beds around them to be deformed, they may be considered partly diagenetic in origin. The fact that many are flat bottomed allows the assumption, however, that part of their growth was on an open sea floor. The mechanism for growth is somewhat obscure. Probably, original colloidal calcium carbonate in the mud formed a cluster or nucleus. Ramberg (1957, p. 222) pointed out that this happens because aggregation decreases the total free energy in the material, a tendency which exists throughout nature. Once a nucleus has been formed, colloidal calcite and ionic carbonate are continually attracted. Most of the concretions in this area are spheroidal to sub-spheroidal, indicating there was little pore fluid movement to disturb growth. The elongation of some concretions may have been caused by diagenetic growth along bedding planes or by sediment load before the complete lithification of the concretion.

Although minor in comparative thickness, the coarser clastic units of this deep-water lithosome are nevertheless important. The conglomerate, sandstone, and siltstone, with the included fossils and primary structures, have probably been produced by the action of turbidity currents (Kuenen and Migliorini,
1950; Cook, 1959; Knill, 1959; Bouma, 1962; Potter and Pettijohn, 1963; Bouma and Brouwer, 1965; Dott, 1964). Because these sediments thin to the south and become finer in that direction, the currents probably flowed from north to south. This is generally supported by the measurements taken on oriented sedimentary structures (Figure 5). Different lithic ratios and different orientations in groups of sedimentary structures show that the currents did not have exactly the same source.

The conglomerate of the coarse clastic units of the Ogo Member were originally derived from the surrounding metamorphic terrain. Because of the clast roundness, however, they must have been worked by normal currents or surf action before any submarine transport. Such material probably built up along a coastal margin until becoming unstable and being distributed by turbidity currents, submarine mudflows, slumps, and some long-shore bottom currents.

Traditionally, these sediments of the Sacramento Valley have been interpreted as having been deposited in a deep marine trough with the present Coast Ranges having been subjected to subaerial erosion. However, recent measurements of large numbers of directional current structures (Ojakangas, 1964, 1966) indicate a gross sediment transport from north to south all along the west side of the present valley. This is consistent with the measurements presented in this report. The total amount of time
represented in the deposition of the Budden Canyon Formation of the map is almost entirely taken up in the shales of the Ogo Member. The high energy environments of the basal conglomerates and the coarse clastic interbeds were most likely geologically instantaneous. The fact that more of these interbedded clastics are found in the Lower Cretaceous strata than in the Upper is possibly a reflection of greater tectonic activity during Early Cretaceous times.
CHAPTER IV

STRUCTURE

Introduction

In the Klamath Mountains basement complex, only the recent general work of Irwin (1960) and the more limited studies by Davis et al. (1965) are notable in their treatment of the geologic structure. Investigations of the sedimentary rocks of the Sacramento Valley which have secondarily treated structure include Harrington (1942), Murphy (1954), Rodda (1959), Lachenbruch (1961), and Murphy et al. (1964). Within this area specifically, only the reconnaissance mapping of Peterson (in: Murphy et al., 1964, Figure 2) has been published and no discussion was included. The study of nearby clastic intrusions by Peterson (1966) also has structural implications.

Because the mapped area lies at the approximate junction of the Klamath Mountains, northern Coast Ranges, and Sacramento Valley provinces, it has received the structural influences of all of these. Because each of these provinces has a distinct tectonic history, this area, bounded by these provinces, has a particularly complex structural history. This is a reflection of the fact that most of northern California has been structurally mobile through much of the time from the Paleozoic to the present.
The various units of the metamorphic basement in this area retain the general northwest-southeast structural trend of the western Paleozoic and Triassic belt. However, because of the close lithologic similarities and the generally poor exposures, other structural relations are not known here. The dominant over-all feature of the Budden Canyon Formation is its rather monotonous, homoclinal dip to the east. The dips of these strata generally are greater near the basement exposures and decrease to the east, however, they change locally near the various faults. In the southern portion of the area the stratal units strike northwesterly. Towards the north, the strike generally trends in an almost north-south manner; the change reflects the approach to the axis of the northwestern Sacramento Valley synclinorium. Faulting is probably of minor significance in most of the Cretaceous strata, although joint sets occur everywhere.

The over-all structural pattern is best exposed, and most complicated, along the contact of the sedimentary succession and the basement complex. Here, faulting has caused significant separation of the units. Such faulting occurs on two scales. First, as the relatively large, transcurrent faults, most of which are vertical or of a very high angle and which may have great displacement, and second, as much smaller faults and unmappable fractures. Major folding of the sediments in this area, other than the large scale bowing of the synclinorium, seems to
be restricted to the shallow southeast plunging syncline of the Platina outlier.

**Faulting and Jointing, Description**

The structural pattern of the map area is dominated by an inter-related system of high angle faults which are largely localized along the basement-sediment contact. Most of these faults, and their associated minor structures, are systematically arranged in this area and are, in turn, part of a much larger system in the northwestern Sacramento Valley. The names of the larger faults which have been used in this report are shown on Plate 1.

Exposures in Beegum Creek of drag folds and the topographic expression of the Arbuckle and Whiteman faults suggest that they are reverse separation structures with very steep dip to the northeast. Mapping north of this area shows that the Arbuckle fault extends northwest across the Platina-Ono road where it has produced a right separation of the basement-sediment contact. Both of these faults have caused uplift of their northeastern sides. The northeastern block of the Arbuckle fault exhibits about five hundred feet of topographic relief over the downdropped side while the upthrown block of the Whiteman fault is over six hundred feet above the opposite side. The relief of the fault line scarps is considerably greater for both faults north of the map boundary. Because of the lithologic similarities, the determination of slip is not possible.
The generally uniform northwest-southeast strike of these two faults is continued to the west by the Section 13, Sulphur Gulch, and Goldsborough faults. These, like the Arbuckle and Whiteman faults, extend a short distance on either side of the basement-sediment contact and cannot be traced any farther. The Goldsborough fault seems to be bracketed between the fault contact of the Platina outlier to the northwest and the Beegum fault to the southeast. There is no direct evidence regarding the nature of the true movement of the Section 13, Sulphur Gulch, or Goldsborough faults; the separation of the basement-sediment contact is of a right-lateral sense. Because the separation is the same as the Arbuckle and Whiteman reverse faults, and because they continue the same trend, these are suggested to also be reverse slip features. Unlike the Whiteman and Arbuckle faults in the northeastern portion of this area, these have little topographic expression; their recognition is based on lithologic offsets, a few poorly exposed shear zones, areas of intense jointing, and the occurrence of both fresh and mineralized springs. Small pods of highly sheared serpentine were also found along some of these faults. This group is interpreted as being very high angle, largely on the basis of the fact that their traces are largely unaffected by topographic irregularities.

The Goldsborough fault is the westernmost of the faults which trend directly northwest-southeast. Another fault with
similar strike, but apparently not directly connected to the others of the trend, is the Juniper Flat fault. This is the only major fault out in the sedimentary sequence of this area. Drag folding and slickensides in Big Salt Creek indicate that the latest movement on this fault was reverse slip with the northeastern side up. This fault is one of the few in the area with an observable lineament on the aerial photographs. In the yet unpublished geologic map of the Ono quadrangle, M. A. Murphy has shown the Corral Gulch extension of this fault to continue to the southeast across Highway 36 (Q. A. Aune, California Division of Mines, personal communication, 1965).

Probably belonging to the same general system of these faults is the N. 75° W. striking Kelsey Gulch fault which is traceable farther than any of the others. This fault forms the southern margin of the wedge-shaped block of Sugarloaf Mountain in the northwest-central portion of the area. It is defined by a chaotic disturbance where it crosses the Tedock road and by the termination of a limestone body and the Rector Member conglomerate.

Trending at about 60° to 70° acute angles to these faults is another set of approximately northeast striking faults. These include the Pattymocus, Beegum Peak, Beegum, and Platina faults. Wherever the traces of the faults of the two sets intersect there is a termination of one fault, but no apparent offset continua-
tion on the other side. This northeast-trending set is generally better defined because of the variety of lithic types which are offset. There is also a number of small serpentine bodies and several springs along these faults. As with most of the others, these faults have little topographic expression. This latter set of faults is also interpreted as being almost vertical and of possible reverse slip, however, the lateral separation is definitely to the left instead of to the right. This left separation is particularly evident in the offset of the gabbroic intrusion and the Knoxville Formation-Rector Member contact by the Patty-mocus fault. Here the shale unit has a lateral separation of 3,100 feet. Along the Beegum fault the Rector Member exhibits a left separation of 5,000 feet. Because of the field evidences within the map area only, this writer feels that most of the movement on all of these faults has been reverse slip. The suggestion that some of the faults in the northwestern Sacramento Valley are right-lateral slip features (Peterson, 1966) cannot be disregarded, however. If compression accompanied the deformational forces which produced the faulting, some lateral slip is to be expected.

There are numerous smaller faults which have been mapped in this area, many of which fit directly into the system of the larger faults. These have had minor movement and have been mapped on the basis of local lithologic offsets and by a few linear
trends on the aerial photographs. In some places such faults are accompanied by small serpentine bodies (as the one in the metasedimentary pendant in section 8, T. 28 N., R. 9 W.). Particularly numerous also are the small normal and reverse slip faults in the Ogo Member.

There is no evidence here to suggest that a large fault of regional scale extends through this area along the Rector-Ogo contact (as reported by Q. A. Aune, California Division of Mines, unpublished geologic map of Tehama County, personal communication, 1965-66). The suggestion for such a fault is based on limestone body truncation and serpentine shear pods in the Hall City area of the Dubakella quadrangle and the linear occurrence of thermal springs and various topographic trends in the Colyear Springs quadrangle (Figure 2). The only direct suggestion of such a feature in this area is the distinct topographic break between the Rector and Ogo members; this form is interpreted by this writer as having formed by differential erosion along the contact.

Intimately related to the faulting, but even more universally occurring, are the numerous joint features of this area. These are distinct planes of parting along which movement has not exceeded one foot, and in most cases not any has taken place. Analysis of over seventy-five joint measurements suggests that these are systematic and are characterized in plan view by one or more sets of almost parallel partings. Most commonly they
occur as paired sets of diagonal joints with very steep dips. This steep dip is reflected in the peripheral concentration of joint plane normals when plotted on equal-area projections. (Figure 6). The joint orientations bear little relation to the attitudes of the rocks in which they appear, however, they have received direct influence from the faults in the area. Maximum joint occurrences in numbers of systems, density, and variability appear near the last mappable portion of the faults, particularly in the sedimentary rocks. There is also a general trend for the strikes of many of the joints to parallel the strike of the nearest large fault. This is indicated by the groupings of plots of poles to joint surfaces opposite the fault strike in the projections of Figure 6. Many of the joints, both in the metamorphic and in the sedimentary rocks, are filled with secondary calcite and, less commonly, gypsum. In all cases the joints are more common in the Ogo Member shale than anywhere else in the area.

Numerous fracture-cleavages (DeSitter, 1956, p. 99) are locally similar in appearance to some of the joints but are not directly related to them. The fracture-cleavages have been developed by the drag of coarse sandstone beds on some of the thin shale units. These are best exposed along Beegum Creek and were caused here by the movement of the competent Ogo Member sandstone beds by the reverse faulting of the Arbuckle and Whiteman faults. Little, if any, movement has taken place on the
cleavage surfaces; the property is exhibited simply as closely spaced partings. Such shale cleavages form acute angles of about forty-five degrees with the sandstone beds.

Folding, Descriptive

Large scale folding occurs in the Platina outlier. Here, the shale and coarser clastic interbeds of the Ogo Member have been folded into a broad, shallow, southeasterly plunging syncline. This feature is largely symmetrical. The plunge appears to be rather constant and may be as great as twenty degrees. The southeastern limit of this fold is in fault contact with the basement units. It is of interest to note that this small syncline has approximately the same orientation and plunge as the much larger northwest Sacramento Valley synclinorium.

Numerous smaller folds occur throughout the area in the form of drag folds along small faults and as associated monoclinal flexures. These are best exposed in the various road cuts which pass through the shale of the Ogo Member. These are too limited to be mapped on the scale of Plate 1 of this report.

Structural Interpretation

Of the long and varied tectonic history of this region, only the structural results of the late Mesozoic and Cenozoic episodes are moderately well exposed. These include the larger faults and the homoclinal attitude of the Sacramento Valley
FIGURE 6

Plots of poles to joint planes on equal-area projections. Horizontal poles included on both hemispheres. Strikes of nearby faults shown for each group.
sediments. Obviously, there are remnants of earlier structural disturbance, however, these have largely been obscured. For example, one definitely pre-Knoxville Formation fault was found (section 23, T. 28 N., R. 9 W.). It truncates the linear gabbroic intrusion and is covered by the conglomerate member of the Knoxville.

To the north of this area, Davis et al. (1965) have found that the basement rocks of the south-central portion of the Klamath Mountains have been affected by two orogenic phases which can be distinguished by their structural and textural features. These seem to correspond in this area, first, to the middle Late Jurassic phase which produced the metamorphism, associated folding, and the following ultramafic and basic intrusions of the Applegate Formation and secondly, to the later orogenies which produced most of the large scale folding and faulting.

Although the Klamath Mountains province was relatively inactive during the Cenozoic movements of the northern Coast Ranges, the southern end, and therefore this area, was nonetheless affected. Taliaferro (1943), Weaver (1949), and Gealey (1950), in their study of the better exposures of the Coast Ranges units, have been able to discern at least nine different orogenic pulses from the beginning of the Paleocene to the end of the Pliocene, the latest phase started in the Pleistocene and has continued to the present. The total orogenic effect has been
referred to as the Westside Uplift (Safonov, 1962, p. 85). It is generally agreed that the faulting and much of the homoclinal attitudes in the Sacramento Valley were produced by one of these later pulses (Harrington, 1942; Dondanville, 1958; Rodda, 1959; Safonov, 1962).

In this area, because the Lower Cretaceous rocks are the youngest exposed, it is not possible to date the exact time of the structural deformation. There was probably some amount of tilting during the Cretaceous which started the formation of the Sacramento Valley westside homoclinate. The possibility of uplift along the west is indicated by an inferred western source of some of the sediments to the south of this area (Dondanville, 1958; Young, 1958) and by the coarsening of some of the sediments in that direction. Such uplift must have occurred in stages as evidenced by several intra-Cretaceous unconformities (Peterson, 1964). The major faulting probably took place prior to the Pliocene because, in the Ono area, the Pliocene strata are not cut by the faults.

The systematic arrangement of the large faults of the mapped area suggests that they resulted from a single stress system. This writer believes that it was the same general stress which formed the final structure of the northwestern Sacramento Valley as a whole also formed these faults. In this area, the Beegum-Goldsborough fault intersection forms an acute angle of
about sixty-five degrees. Similar angular relations would exist between the other generally northwest and northeast trending faults if they were extended to intersect. A number of smaller faults strike almost at right angles to the larger ones. Such relations suggest that these faults are members of a system and that they were formed in response to a common major stress.

None of the major faults extend very far into the Cretaceous section. Being that the rocks of the basement complex are the most ridged, faulting was probably initiated here and continued into the overlying material. Because most of the sedimentary rocks are thinly-laminated, highly fissile shale, the stress was not retained in a single plane of rupture and hence, no single fault was able to continue. Instead the strain was released in the rather ductile shale in the form of many systematic joint sets. The strikes of many of these joints are parallel to the fault which caused them (Figure 6).
CHAPTER V

HISTORICAL RESUME

Nothing has been written in regard to the actual environment of formation of the rocks of the western Paleozoic and Triassic belt which form the basement complex in this area. Their original content of quartz sandstone, dark shale, conglomerate, limestone, and several types of volcanic rocks requires an environment which would supply such varied units, many of which are interbedded with each other. For this, the writer suggests a shelf-slope marine situation, although he recognizes that some of the rocks are probably of widely different ages. The earliest age of the rocks is unknown while the latest age, that of the fossiliferous limestones, is Triassic.

Metamorphism of what is now the basement complex probably occurred very early in the set of events that included the Nevadan orogeny. Regional metamorphism proceeded to the greenschist facies and ended with the Kimmeridgian intrusion of a regional ultramafic sheet which was itself almost completely serpentinitized. This was followed by minor gabbro-diorite intrusions with the production of slight contact metamorphism.

Latest Portlandian deposition (Knoxville) started directly on the basement unconformity. Marine onlap probably formed the basal conglomerate member of the Knoxville (?) Formation. Uplift
in response to the Late Jurassic Diablan orogeny removed most of the Knoxville sediments from this area, if they were ever present. Most likely no deposition occurred until the renewed Hauerivian transgression which formed the Rector Member of the Budden Canyon Formation. Quiescence during most of the remainder of the Neocomian marked the moderately deep shelf or trough environment which produced the shales of the Ogo Member. The relatively slow accumulation of the shale material was periodically interrupted by coarse clastic detritus which had its transporting current direction from the north. Periodic, sediment-laden turbidity currents are interpreted as best explaining the arrangement of these coarse clastic units in the Ogo Member. These flysch-like deposits are similar to those of the Upper Mesozoic further south in the Sacramento Valley and may represent a miogeosynclinal facies of the original Franciscan eugeosyncline to the west (Bailey et al., 1964).

The post-Turonian/pre-Pliocene Coast Range orogeny brought an end to this type of sedimentation (Peterson, 1966). There is no evidence that Eocene to Miocene rock units ever extended this far north. Minor amounts of Plio-Pleistocene, probably non-marine, clastics to the northeast of this area indicate that the deposits of the Red Bluff or Tehama formations extended this far to the west. The latest Cretaceous deformation induced faulting in this area and exposed the region to subaerial erosion. This erosion
stripped away all post-Cretaceous rocks in the map area and formed the Budden Canyon Formation outliers.

Anderson, F. M., 1933, Type area of Jurassic Knoxville series of California: Pan-Am. Geologist, v. 60, p. 175-188


_____, 1945, Knoxville series in the California Mesozoic: Geol. Soc. America Bull., v. 56, p. 909-1014


_____, 1962, Late Mesozoic stratigraphy of the Sacramento Valley, p. 3-16 in San Joaquin Geological Society Selected Papers, v. 1


Dondanville, R. F., 1958, The geology of part of northwestern Glenn County, California: Univ. California, unpublished M. S. thesis


Gabb, W., 1864, Paleontology of California, p. 55-243 in Paleontology, v. I, sec. 4: California Geol. Survey


Harrington, W. C., 1942, Geology of the Paskenta district, Tehama County, California: Univ. California, unpublished M. S. thesis


Hershey, O. H., 1901, Metamorphic formations of northwestern California: Am. Geologist, p. 225-245


Kuenen, P. H., and Migliorini, C. I., 1950, Turbidity currents as a cause of graded bedding: Jour. Geol., v. 58, p. 91-127


Merriam, C. W., 1961, Silurian and Devonian rocks of the Klamath Mountains, California, p. C188-C190 in U. S. Geol. Survey Prof. Paper 424-C


Raymond, M. S., 1958, The physical stratigraphy of the Upper Mesozoic sediments of a portion of Glenn and Tehama counties, California: Univ. California, unpublished M. S. thesis

Rodd, P. U., 1959, Geology and paleontology of a portion of Shasta County, California: Univ. California, unpublished Ph.D. thesis


ABSTRACT
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Geologic mapping in the extreme northwest portion of the Sacramento Valley and southern Klamath Mountains has revealed basement exposures of the metamorphosed Triassic (?) Applegate Formation which are unconformably overlain by sedimentary rocks of portions of the Knoxville (?) Formation (Upper Jurassic, Portlandian) and the Budden Canyon Formation (Lower Cretaceous, Hauterivian). The greenschist facies metamorphic rocks which form the southern end of the Western Paleozoic and Triassic belt of the Klamath Mountains consists of quartzites, metacherts, and greenstones, with minor amounts of slightly altered volcanic rocks, limestones, argillites, and conglomerates. These rocks were intruded by Jurassic peridotite (now mostly serpentinite) followed by gabbro.

In the southwestern portion of the map area the basal polymictic conglomerates of the Knoxville (?) Formation, averaging about 2,800 feet in thickness, are separated from the basement complex by a marked nonconformity. A wedge of dark shale, thinning to the north, separates the Knoxville from the Budden Canyon Formation.

The basal conglomerates of the Rector Member of the Budden Canyon Formation are lithologically similar to the Knoxville conglomerates. These outcrop intermittently with variable thickness
(0 to 900 feet) in the north and thicken to about 3,000 feet in the south where they overlie the Knoxville.

The Ogo Member of the Budden Canyon Formation, which overlies the Rector Member and locally rests on the basement, consists almost entirely of thinly bedded, dark marine shales which are intertongued with minor, relatively thin, coarse clastic units which had their current source from the north. In this area the Ogo Member may be as thick as 10,300 feet. Sediments of both these Lower Cretaceous members also occur as small outliers in the northwest part of the map area.

The sedimentary rocks are exposed in an easterly dipping homocl ine, while the complex litho-structural grain of the basement units trend northwest-southeast. Opposing sets of high angle to vertical, probable reverse faults form acute angles of intersection of approximately sixty-five degrees; the northeast trending set has left lateral separation while the northwest trending set exhibits right lateral separation. In the northeastern portion, two moderately large reverse faults have uplifted blocks on their hanging wall side which have over 600 feet of topographic relief. Major folding is represented only in the gently southeasterly plunging syncline of the sedimentary Platina outlier.
GEOLOGIC MAP
SOUTHEASTERN PORTION OF THE CHANCELULLA PEAK QUADRANGLE,
SHASTA AND TEHAMA COUNTIES, CALIFORNIA

Topographic base map enlarged from Chancelulla Peak Quadrangle, California, 15 Minute Series (Topographic), N4015-W12245/15, 1951, James Rodell Maytum.

EXPLANATION
Sedimentary and Metamorphic Rocks

Opa Member
Heavy stippled and outlined. Reddy sandstone, some clay, siltstone, chert, and locally tuffaceous sandstone and siltstone.

Rector Member
Slate and dark shale, similar to Shingle member but more massive and non fissile.

UNCONFORMITY (?)

Shingle Member (intertong)
Thin beds of shale, sandstone, and siltstone.

Conglomerate Member (interbed)
Alternating thin beds of sandstone and shale.

Applegate Formation
Metamorphic rocks (red) including quartzite, schist, and gneiss, with Similar sediments and metavolcanics.

Intrusive Rocks
Gabbro
Coarse porphyritic gabbro with minor diorite. Light grayish green.

Ultramatic Rocks
Coarse porphyriatic amphibolite (black) with minor diorite.

SYMBOLS

DRAINAGE: noted where considered to be active.
;
PAINT, shaded tone, darker where considered to be important, showing drainage of oil, or approximate extent.

UNCONFORMITY, heavy stipple and outline.

VOLCANIC, varying in porphyry, darker where inferred, showing drainage of oil, or approximate extent.

STRATA: shown by protected color, dotted if of unknown age.

GROUND WATER, faint color, shaded where summer.

GREEN, applied to spit of vegetation, shaded for approximate extent.

SHORELINE, faint color, shaded for approximate extent.

APPROXIMATE MSA Datum.

UTM, 10,000-foot grid based on California coordinate system, zone 1; 10,000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue.

SCALE

CONTOUR INTERVAL 100 FEET

Geology by James F. Maytum
San Diego State College - 1951

Polyline projection: 1927 North American datum
10,000-foot grid based on California coordinate system, zone 1
10,000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

APPROXIMATE MEAN DEVIATION, 1951.