THE GEOLOGY OF THE
SUPLEE PALEOZOIC SERIES OF CENTRAL OREGON

by

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A THESIS

submitted to the

OREGON STATE AGRICULTURAL COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

January 1934

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ACKNOWLEDGEMENT

Since no individual is sufficient unto himself, his accomplishments must, therefore, be in large part a composite, the integral parts of which are, those persons who are responsible for the training which makes accomplishment possible; those persons who give actual assistance on the problem at hand and associations from whom valuable ideas are obtained. With these things in mind and this thesis representing the degree of accomplishment, the writer wishes to express appreciation and gratitude to Dr. E.L. Packard, Dr. W.D. Wilkinson, Dr. E.T. Hodge, and Dr. W.D. Smith, members of the Faculty of the Department of Geology, for the mental equipment with which he has been supplied during the period of University training; to Dr. E.L. Packard who suggested the problem undertaken in the thesis and gave valuable time and assistance to aid in its completion; to B.N. Gonzales, his colleague for field assistance and suggestions; to Dr. W.D. Wilkinson and Dr. W.D. Smith for suggestions on various phases of the problem; to Wayne Felts, fellow student for field and financial assistance; to Francis Peck, fellow student for field assistance; to I.M. and O.C. Mill, ranchers near Suplee for the use of their maps and buildings; and to my fellow students who during daily intercourse and discussion dropped the seed of helpful ideas.

TABLE OF CONTENTS

Block diagram of the Suplee Paleozoic Series

The structure of the series is anticlinal as shown by the cross section through the central part of the block.

Lithologically the series consists of limestones, cherts, grits and conglomerates with intrusive bodies of an intermediate composition.

The topography is very expressive of the structure and lithology, and variations in structure and lithology are always accompanied by corresponding variations in topography. The limestones, igneous material and cherts stand out as ridges, while the valleys and lower areas are in the mechanical sediments.

The streams are not superimposed consequents but rather consequents which have become entrenched along lines of structural weakness.

The late Tertiary lavas of a basaltic and rhyolitic nature form an escarpment of semi-circular outline around the area, presenting a marked topography unconformity with the Paleozoic.

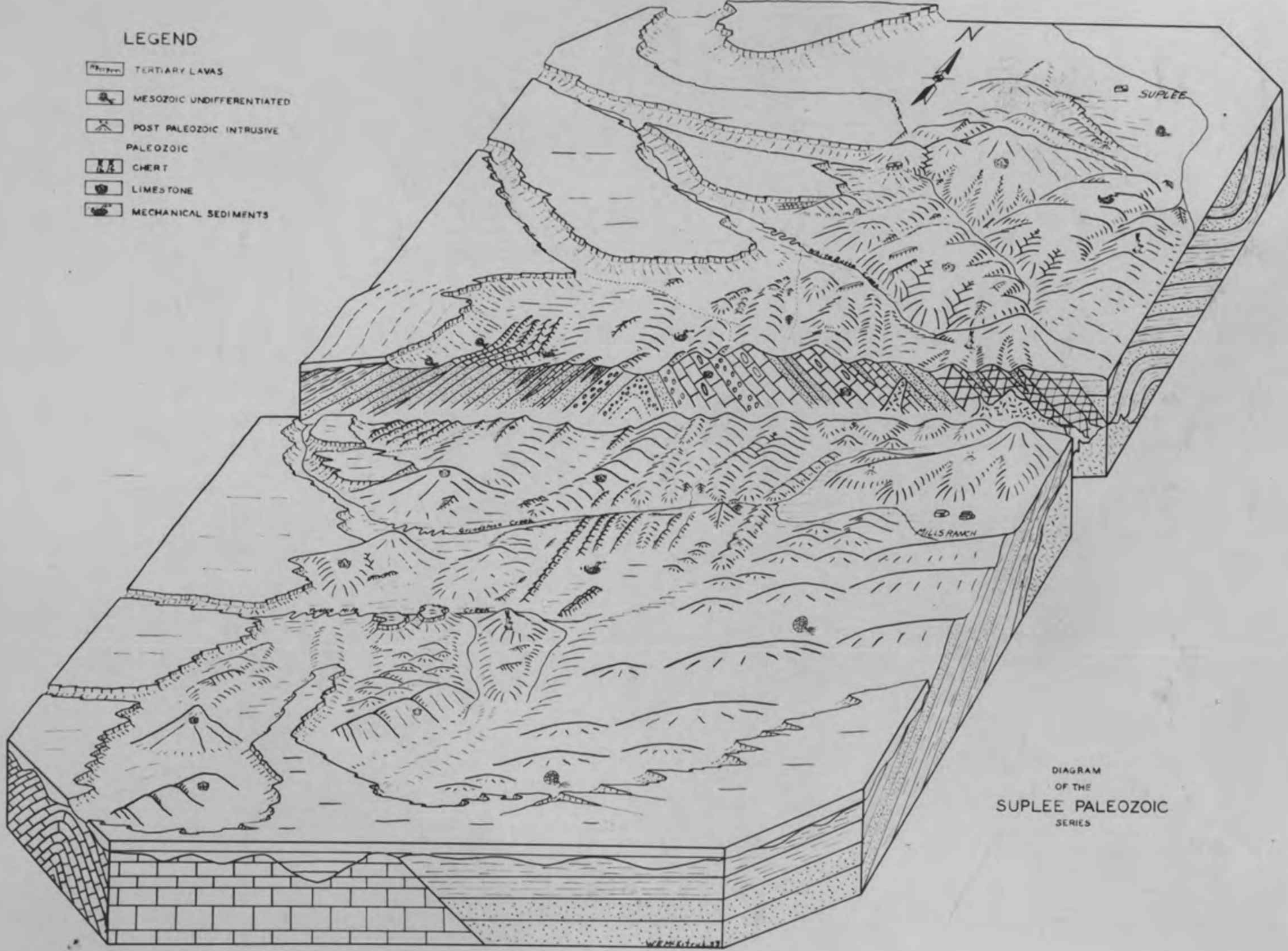

DIAGRAM
OF THE
SUPLEE PALEOZOIC
SERIES

INTRODUCTION

A. Location and extent

The Suplee Paleozoic area occurs as a window in the Tertiary lavas near the headwaters of the Crooked River south of Suplee, Crook County, Oregon. The tributaries of that stream, Grindstone and Twelve Mile Creeks, head in the area and cut directly across it. The area covers approximately sixty square miles being about twelve miles long and five miles wide at the widest part, and elongated in a general north-south direction. It is included in T 17-18-19 S. and R 24-25 E mostly in R 25 E.

That part of the topography which lies north of a line from Wade Butte N.W. $\frac{1}{4}$ S 24 T 18 S R 24 E to Iron Mountain S.E. $\frac{1}{4}$ S 23 T 18 S R 25 E is included in the advance sheet of the Dayville Quadrangle which has been published by the United States Geological Survey after the field work for this thesis was completed.

B. Previous geologic work

Previous geologic work relating to the Suplee area may be found in any one of the following papers by Packard,[1] Schenk,[2]

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1 Packard, Earl L. Discovery of the Baird Mississippian Fauna in Central Oregon. Pan Am. Geol. Vol. 49, No. 4, 1928. A new section of Paleozoic and Mesozoic rocks of Central Oregon. Amer. Jour. Sci. Vol. 15, 1928. A contribution to the Paleozoic Geology of Central Oregon. Carn. Inst. Wash. Paleo. Pub. No. 418, 1932.

2 Schenk, Edward T. The stratigraphy and paleontology of the Triassic of the Suplee region of Central Oregon. Master's thesis, U. of O. 1931

Gonzales,[3] or Lupher[4]. A repetition of this will not be made here.

C. Paleontology and correlation

The paleontology of this Suplee area has been studied in part by B.N. Gonzales and the results of this work are recorded in his thesis. His works show that the organisms are related to European and Asiatic faunas and that they lived in an arm of a sea which extended from what is now Western Europe through northern Europe and Asia, and Alaska southward into California. Faunas similar to the Suplee formation are found in the Baird formation of Northern California and in southeastern Alaska. The fauna is assigned to the Visean division of the Dinantian or lower Carboniferous.

"The faunal study is primarily concerned with the brachiopods since that group is most abundantly represented in the fauna and since literature pertaining to contemporaneous Euroasiatic brachiopods was available. These Oregon beds have yielded a large and varied fauna much of which is as yet unstudied representing Foraminifera, Anthrozoa, Crinoidea, Milluscoidea, and Mollusca. Only a few characteristic froms among these other groups are herein described.

"The brachiopods constitute a large portion of the Suplee fauna and productida probably represent 75% of that group. Such a high percentage of those forms is indicative of Lower Carboniferous throughout the world. Next in abundance are the corals which will

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3 Gonzales. A contribution to the Paleontology of the Paleozoic faunas of Central Oregon. Master's thesis, U. of O., 1933.

4 Lupher, R.L. Stratigraphy and correlation of the Marine Jurassic deposits of Central Oregon. Doctorate thesis, Cal. Inst. Tech., 1930.

include at least ten species when studied in detail. In places they constitute large masses composed almost exclusively of the genus Lithostrotion. Although numberous specimens of round crinoid stems have been collected, heads have not been found. The bryzoans consist largely of the encrusting types such as Polypora, but they no where make up any considerable body of the limestone. Only a few clams, an occasional snail and a few cephalopods have been recognized. Foraminifera have been found in Paleozoic limestones in the overlying basal Triassic, but these have not been discovered in place by the writer and are not considered in this report.

"This fauna contains a large percentage of brachiopods that have been described from the Paleozoic of Northern Europe and from many places in Asia. These Euroasiatic species include such well known forms as: Dictyoclostus semireticulatus (Martin), D. flemingi (Sowberby), D. inflatus (Tschernyschew), Echinoconchus elegans (M'Coy), Buxtonia scabricula (Martin), Juresania iuresanensis (Tschernyschew), Striatifera striata (Fisher), S. undata (Defrance), Gigantella giganteus (Martin), var. Oregonensis, n. sp. Gigantella maxima (M'Coy), Linoproductua cora (D'Orbigny), Eomarginifera viseeniana (Chao), Productus sp., Lingula mytiloides, (Sowerby), Derbya regularis (Waagen), Spirifer striatus (Martin), Athyria lamellosa (L'Eveille), Dilesma sp., Schizophoria sp., Chonetina sp., Lithostrotion sp., and Polupora. Many of these forms have never before been recognized in North America. The list includes several of the characteristic species of the wide spread Productus giganteus fauna.

"The species Productus giganteus (Martin), (now referred to as

Gigantella) for which the fauna is named in represented at Suplee by a form which is subspecifically separable from the typical form and is herin described as the **variety** oregonensis. This large productid occurs in great numbers in the Suplee area making up large limestone outcrops, some of which are 75 feet long and 15 feet wide. The shells are piled upon one another in such large numbers that it is almost impossible to obtain a complete specimen. A reconstructed shell gives an inkling as to the size of this enormous brachiopod. It has a height of 140 mm., and a width of 240 mm. The large number of shells show that this species must have been very prolific in the seas. They are found in four large outcrops in the area and on both sides of the anticline equidistant from the anticlinal axis.

"Gigantella maxima (M'Coy) another diagnostic species of the Productus giganteus zone, is very close to the type Gigantella giganteus and is found in two localities in the area with the variety oregonensis. M'Coy in writing the original description of this species says they are frequently one foot in width, but the Oregon shells do not exceed seven inches.

"Striatifera striata (Fisher) is the most abundant brachiopod found in this area and it is very widely distributed throughout all the localities. It is one of the type fossils of the Visean of Europe and Asia and one of the forms which is nearly always found in the Productus giganteus horizon. In the localities where these fossils are found they are very abundant but very fragmentary, so that the complete specimens are quite rare.

"Striatifera undata (Defrance) is common in the Visean rocks of Europe and Asia, it is a very good horizon marker, but not quite as common as Striatifera striata.

"Dictyoclostus semireticulatus (Martin), Buxtonia scabricula, (Martin), Linoproductus cora (D'Orbigny), and Juresenia juresanensis (Tschernyschew) are all long range specimens ranging from the Lower Carboniferous to the Permian, and consequently not of much value for the determination of stratifraphic zones, but they are of a major significance in inter-regional correlation.

"The absence of the species (Eochnoconochus punctatus (Martin) in this area seems quite extraordinary as it is very common in all the Visean beds of Europe and Asia. It has been set up as the genotype for the new genus Echinoconchus and two species of this genus are found in the Oregon collections. They both have many of the characteristics of E. punctatus and are undoubtedly derived from that stock.

"The species Echinoconchus elegans (M'Coy) has been found widely distributed in Europe and Asia and survives even to the Uppermost Carboniferous. It was first described in the Mountain Limestones of England and is one of the characteristic fossils of those beds. This specie occurs in abundance in two Suplee localities.

"New species are relatively few in this area. Since certain foreign literature was not obtainable, it is more than possible that many of the forms which are classed in this paper as near to American species may have been described by foreign authors, but it is certain that they have not been reprinted heretofore in North America.

"The presence of the coral Lithostrotion, which appears to have close affinities with L. irregulare (Phillips) of the European

Visean seems to indicate that the remainder of the corals of the area will undoubtedly show many more European and Asiatic forms."[1]

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1 Gonzales, B.N. A contribution to the Paleontology of the Paleozoic faunas of Central Oregon. Master's thesis, U. of O., 1933

II PHYSIOGRAPHY

A. Topography

In general the topography of the Paleozoic area is in the late mature stage. The slopes are gently rounded except where a more resistant stratum outcrops and preserves the ruggedness of youth.

The limestone hills have a gently rolling subdued expression which is enhanced by the general absence of sagebrush or juniper and the presence of a short grass which in summer becomes brown, adding to the hills a soft velvety appearance. The hills composed of mechanical sediments present a more rugged appearance due to the occasional angular outcrops which protrude through the surface.

The relief of this region is decidedly misleading since the hills are both higher and steeper than they appear unless one is accustomed to making judgments of relief in regions where vegetation is sparce.

Limestone ridges showing mature topography

Two possible explanations for the development of the physiographic features at Wade Butte, figure C being the present stage.

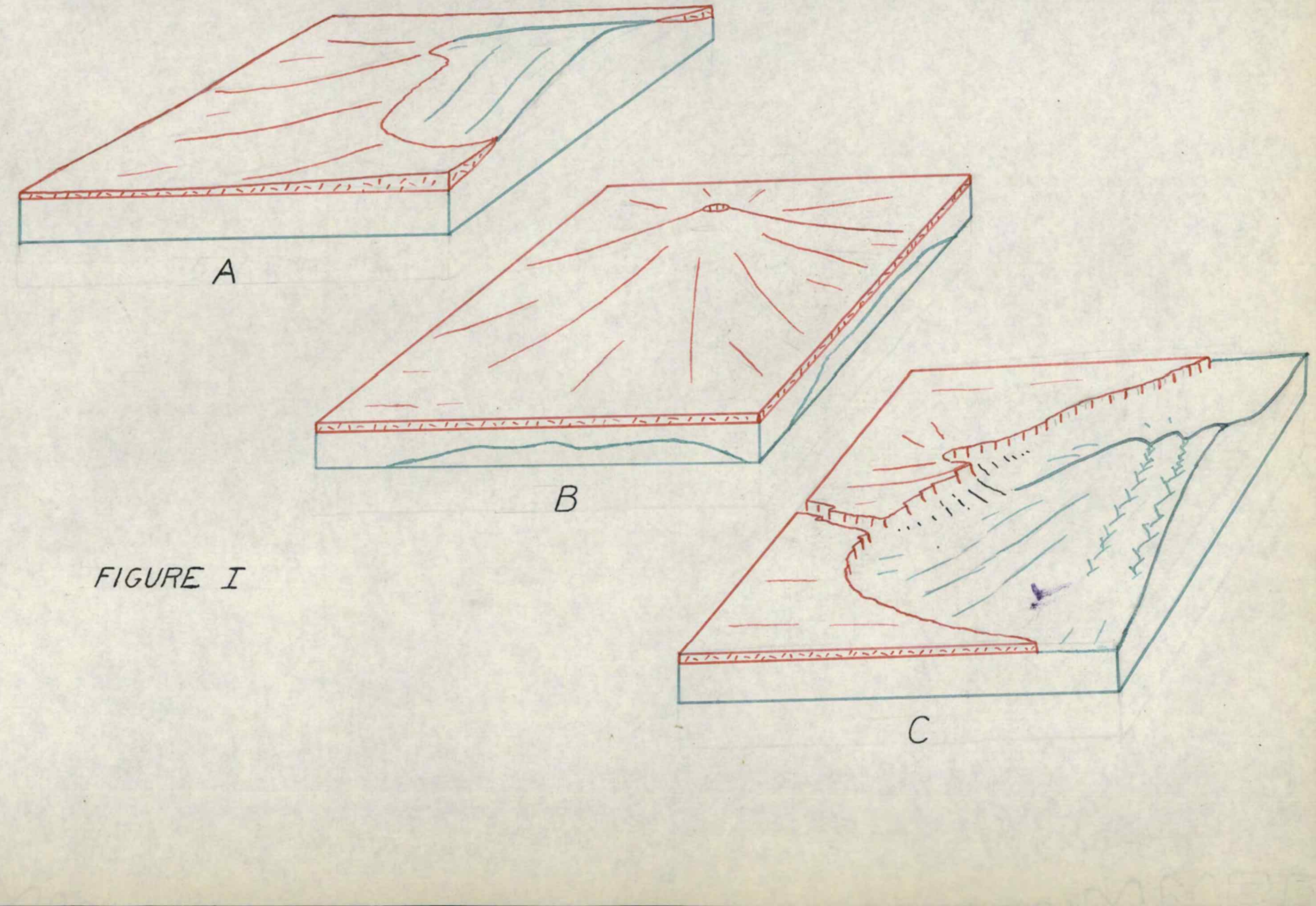
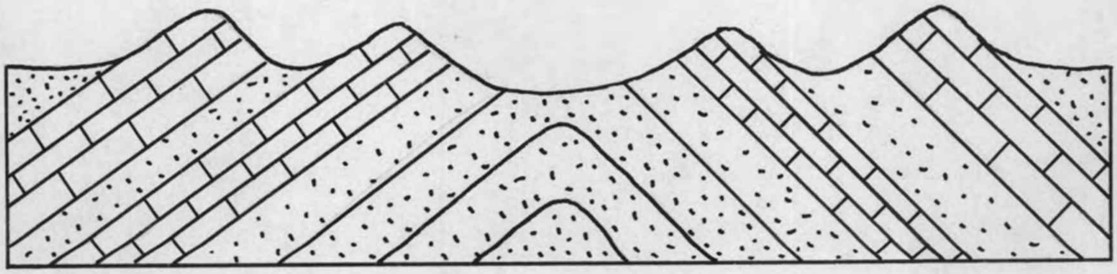


FIGURE I

The higher portions of the area are always composed of limestone or chert, the valleys being carved in the mechanical sediments. This condition is apparently the direct result of the type of climate, which is typically continental. The lack of moisture results in a retardation in the disintegration and decomposition of a homogeneous and soluble material such as the limestones, and the extremes in temperature both seasonal and daily hasten the breakdown of the non-homogeneous mechanical sediments, composed of materials having different co-efficients of expansion, while not appreciably affecting the homogeneous limestones.



Sagebrush does not thrive on the soils derived from the limestones. This may be due to the fact that the soil mantle on the limestone is thin, since the process of creep, greatly accelerated by the extremes in temperature, carries most of the soil into the valleys. However, the sagebrush grows abundantly in the valleys and on the soils derived from the mechanical sediments. Thus contacts between limestones and mechanical sediments can be approximated by the comparative adundance of the sagebrush.

According to Fenneman[1] the region is included in the Harney Section of the Columbia Plateaus--which he describes as a young lava plateau, having features of recent vulcanism with ineffective drainage. The Paleozoic occurs as a window in these lavas since it is bordered on the south, west, and northwest sides by Tertiary lavas of a rhyolitic and basaltic nature which form as a result of subsequent erosion an escarpment of semicircular outline. At the time these lavas were poured out over the area they either abutted directly against the sides of the Paleozoic land mass or covered it over entirely. Conclusive evidence of either possibility has yet to be found but evidence at hand will be presented later.

This Tertiary escarpment is highest in the Central western part of the area at Wade Butte S 24, T 18 S, R 24 E and slopes gently from this point to the West, Northwest and to the Southwest. This higher portion at Wade Butte may have resulted from an uplift along and east-west axis, Fig. I A, or may have been nearer the source of the lavas, the slopes northwest, west and southwest from Wade Butte representing dip slopes of a lava feeder, see Fig. I B and C. The presence of an east-west divide east of Wade Butte terminating at Iron Mountain, S.E. $\frac{1}{4}$ S 23, T 18 S, R 25 E, the highest point in the area, lends plausibility to the first theory, while the absence of evidence for a lava covering over the entire area may nullify the second theory.

The whole Paleozoic area is cut off on the east by a large

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1 Fenneman, N.M. Physiographic divisions of the U.S. Annals of Ass'n of Amer. Geographers. Vol. XVII, No. 4, Dec., 1928.

north-south trending valley. This valley is carved across the strike of Mesozoic sediments, which are folded to form an anticline striking approximately east and west.[1] The west side of this valley is an escarpment composed of cherts and cherty limestone which pass as a wide band entirely through the eastern part of the Paleozoic area from north to south.

This valley may be due to the erosion along the contact of the Mesozoic sediments and the cherts and cherty limestone, the softer Mesozoic sediments being cut away leaving the cherts as an escarpment, or it may be due to faulting. Some detailed work over the area is necessary to bring more field evidence to bear upon the question before it can be definitely settled. However, the following evidence points to faulting:

1. Erosion of the valley across the strike of the Mesozoic strata.

2. Abrupt termination of the Mesozoic strata along the strike, where it abutts against the Paleozoic.

3. Faceted spurs in linear arrangement.

Number 1 could be easily explained by superimposition of Tertiary drainage pattern. However, number 2 would be difficultly explained by any other method except faulting. Number 3 may apply to any escarpment whether due to faulting, the slope of steeply dipping strata, or the upturned and eroded edge of strata. The Paleozoic strata on the escarpment are dipping steeply to the east and if the sediments were eroded away to the east these strata would be left forming an escarpment along their strike upon which facets would

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[1] Personal communication from Dr. Ralph Lupher

tend to develop. Numbers 1 and 3 then may be considered only as corroborative evidence of number 2.

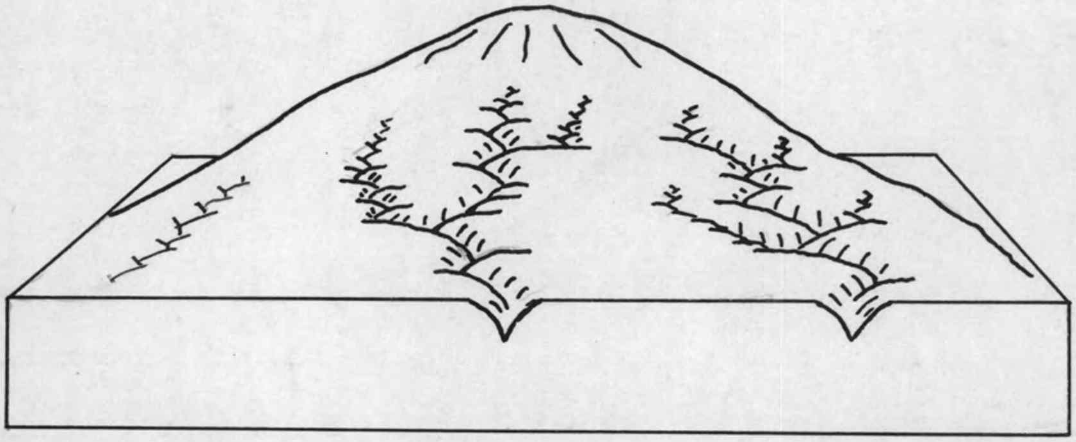
B. Physiographic subsections

Roughly the area may be divided into three distinct physiographic subsections, the topography of each being directly dependent upon and resulting from the structure and lithology of each particular subsection.

As mentioned above the climatic conditions vis., (1) Great extremes in temperature both seasonal and daily. The seasonal change is from 110 degrees F. or above in summer to 40 degrees below zero in winter, or approximately 150 degrees F. range. The daily change in summer is from 110 degrees above zero F. to 35 degrees above zero F. or approximately 75 degrees range. (2) The absence of precipitation over long periods bring about rapid disintegration of the mechanical sediments while not affecting the limestones to such a great extent, consequently the limestones are characteristically the higher points throughout the area. This statement must be modified to cover the case of the cherts which are very resistant and are found as the highest points in the area, e.g. Iron Mountain. The mechanical sediments occur in the valleys and lower portions.

1. Northern Section

The northern section consisting of that part of the area which lies north of North Fork of Trout Creek is characterized by massive limestones and wide chert bands interbedded in the limestones. The result is massive hills the dissection of which is subordinated by the size of the hills. The dissection is noted as small depressions on a massive background, which is characteristic dissection of massive formations.



The main valleys in this region are deep and the sides steep, having a youthful aspect; however, they do not cut a great distance headward into the limestone mass but are confined near the base, the gradient of the valley floor being acutely concave.

The limestones and the cherts blend together and their contacts ordinarily are not apparent from the topography since little differential erosion occurs. Occasionally, however, a chert lens stands up above the limestone resembling a dike.

Structurally the northern section consists mainly of the eastern flank of the anticline, only a small portion of the western flank being exposed on the western margin of the section.

2. Central Section

The central section consists of the area between North Fork of Trout Creek on the north and Grindstone Creek on the south.

This central section may be further divided into an eastern and western section, the dividing line being the crest of the anticline, since limestones predominate on the eastern flank and mechanical sediments predominate on the western flank.

The center of the anticline has been eroded and the valley formed is broad and has gently sloping sides. The intersection of the valley of Grindstone Creek with this valley forms a large oval shaped bowl.

The central section is dominated by the dissection in both eastern and western parts.

In the eastern part differential erosion of alternating beds of limestone and mechanical sediments has resulted in a series of north-south trending ridges, formed of the more resistant limestones, the valleys between the divides having been eroded in the less resistant mechanical sediments.

An east-west divide passes through the central section and the ridges north and south of this divide are parallel to the strike of the steeply dipping beds which is approximately north-south in this section. The north-south ridges of the eastern part have a steep west slope and a gentler east slope indicating an eastward dip of the strata.

Iron Mountain, a rather sharp peak composed of chert and the highest point in the entire area, is on the eastern border of the central section. A short distance southeast of Iron Mountain is

Mills Butte, an igneous mass probably a dike, surpassed in altitude only by Iron Mountain.

The western portion of this region consists of low rounded hills, the relief is less and the general elevation is less than that of the eastern portion. Strike ridges are not common, but occasionally a rugged ridge of grit outcrops forming a small escarpment which may be traced along its strike with little difficulty. A notable example of this is the ridge a short distance west of Mill's Sheep Corral.

3. Southern Section

The southern section includes all the area from Grindstone Creek south to the Tertiary lava rim.

Limestone predominates in this section with the exception of a small area in the eastern part, between Grindstone and Twelve Mile Creeks, which is composed of mechanical sediments, mainly grits.

Tucker and Bucher Buttes are the outstanding features of this southern section.

Tucker Buttes, S 17-18, T 19 S, R 25 E, are a series of buttes evidently derived by the dissection of a southwest striking escarpment resulting from erosion of limestone strata dipping steeply to the southeast.

Bucher Buttes, S 14-23, T 19 S, R 24 E, consist of a series of three buttes in an approximately north-south line. South Bucher Butte is a continuation of the same limestone stratum which forms Tucker Buttes, and is a part of the nose of the plunging anticline.

Central Bucher Butte, which will be referred to hereafter as Bucher Butte and is thus differentiated from the others which will be designated North Bucher Butte and South Bucher Butte, is the highest

Diagram illustrating the development of the physiographic features in the vicinity of Tucker and Bucher Buttes. C represents the present stage.

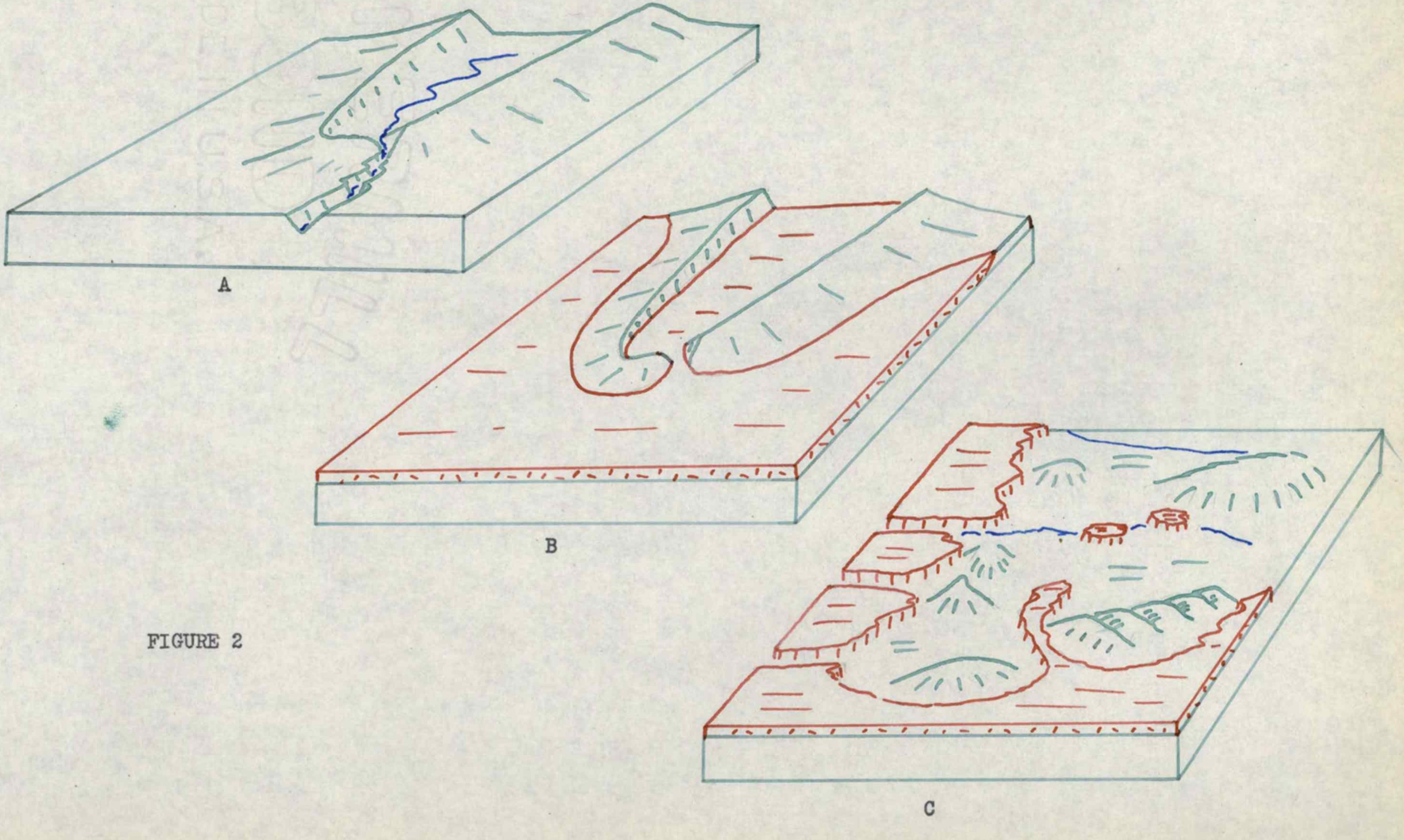


FIGURE 2

of the buttes. It may be part of the western limb of the anticline or part of the vertical strata in the center, its exact relationship to the structure is difficult to determine since it is massive and shows no dips.

Triangulation Point 5, S 6, T 19 S, R 25 E, located on Grindstone Creek on the western edge of the section may be on a part of this limestone mass.

These Buttes were probably originally connected forming a continuous limestone ridge of considerable height similar to Tucker Buttes but higher, that have since been separated by intermittant streams working mostly toward the west. The lava rim is dissected at these places showing that the same processes which dissected the limestone ridge forming Bucher Buttes also cut a channel through the lavas.

The southeast side of the nose of the anticline between Tucker Buttes and South Bucher Butte must have been breached before the outpourings of the Tertiary lavas since some of the hills of lower elevation between the Buttes are capped by Tertiary lavas, which seem to have flowed in upon the Paleozoic from the south probably by way of drainage channels. This together with the fact that the lavas show no tendency to rise abruptly over the limestones from their position at the bast of the buttes seems to indicate that the area was not entirely covered over by the Tertiary lavas, but that the lavas advanced over the area only where it was of lower elevation, i.e., up drainage channels. Fig. 2, A. B. and C.

In the eastern part of this section there is also a wide series of mechanical sediments, which have been eroded below the general level of the limestones. Ridges which trend in an east-west direction due to a pronounced jointing system in this direction are prominent, and this same series of joints may be the cause of the valleys which cut across the strike of the beds instead of superimposition by lava flows.

There is also a ridge of brown chert which slants up quite prominently and is possibly a continuation of the cherts found associated with the limestones in the northern parts of the area, a series of mechanical sediments lying between the chert and limestone formation farther to the west have been eroded out to form a valley which has been cut by headward erosion almost through the southeastern portion of the nose of the anticline.

C. Drainage

The master streams of the area are the two east-west streams, Twelve Mile Creek and Grindstone Creek, separating the southern part of the area from the central part and the two northwest-southeast trending streams,White Butte Creek (U.S.G.S. calls this creek South Fork of Trout Creek), and North Fork of Trout Creek, separating the northern section from the central section.

These master streams cut directly across the strike of the strata, and have cut canyons in the Tertiary rim. Intermittant streams, the direction of which is governed by the strike of the strata are found between these master streams, thus forming a trellis drainage pattern.

The master streams cut entirely across the anticline and head in the eastern margin of the area.

The problem of these east-west trending streams which cut entirely across the area and across the strike of the beds may be resolved into five possibilities:

1. Superimposition by Tertiary lavas.
2. Superimposition by Mesozoic strata.
3. Consequent drainage down the flanks of the anticline.
4. Superimposed by faulting.
5. Jointing.

1. Superimposition by Tertiary lavas.

If these streams were superimposed by Tertiary lavas, evidence of a lava covering over the area is essential. Only two Tertiary remnants have been left which mark lava inroads upon the Paleozoic, one in the northern section between White Butte Creek and North Fork Trout Creek. This remnant is on the western side very close to the Tertiary rim and therefore does not represent an extensive advance by the lavas. The other remnant is in the southern part of the area and extends from the Tertiary rim to the south side of Twelve Mile Creek between Tucker Buttes and Bucher Buttes.

Since these remnants are of lower elevation than the surrounding Paleozoic hills it seems improbable that these remnants can be used as evidence for other than purely local advances of the lava, perhaps up some pre-Tertiary drainage channel.

As further evidence that the lavas did not cover the entire area: the valleys of the master streams are flat bottomed, and have well defined meanders which are beginning to entrench.

Such a condition may have been caused by temporary base leveling. The more resistant lavas, which lapped upon the edges of the

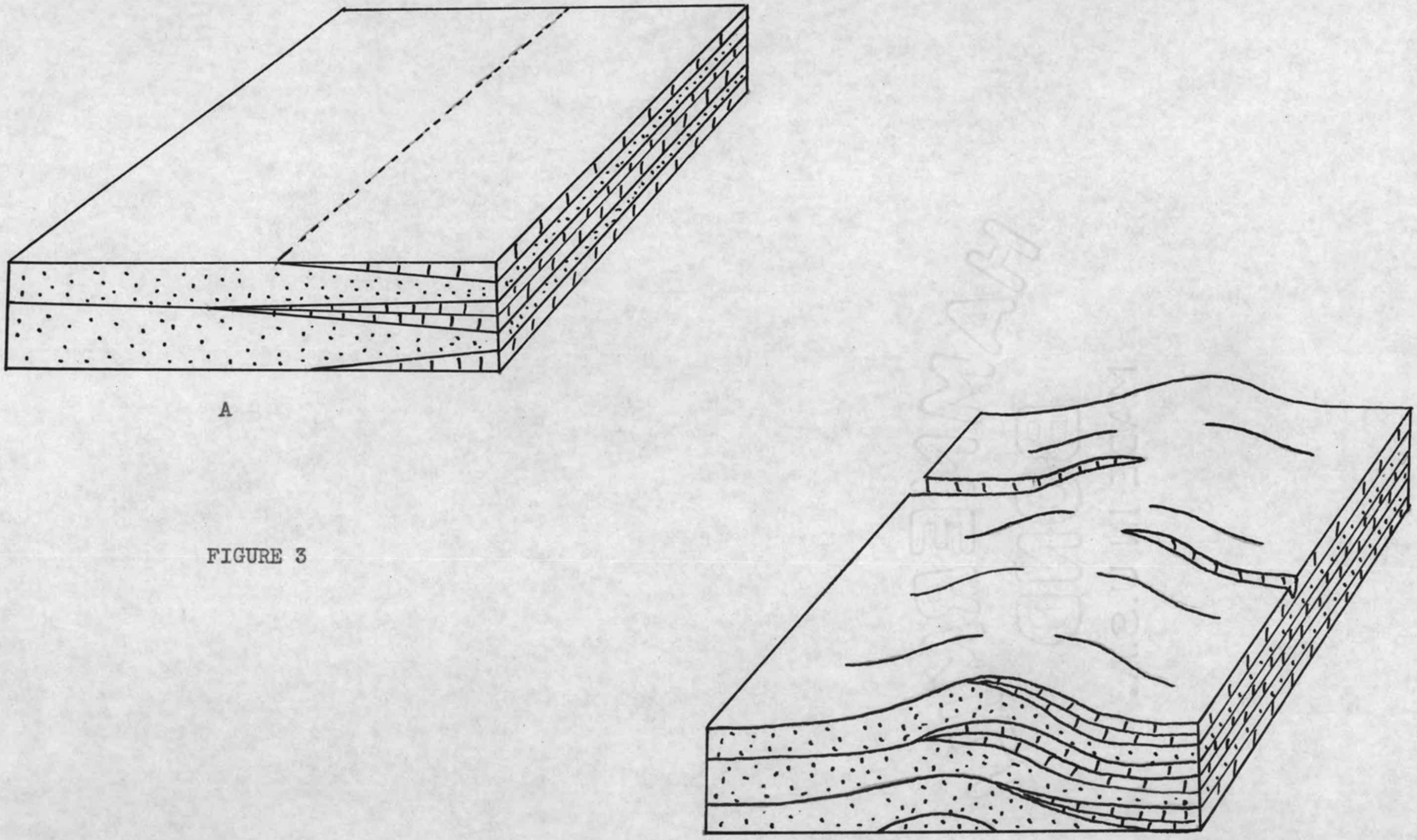
Paleozoic mass forming the obstruction through which the streams must cut before they could erode deeper into the Paleozoic.

2. Superimposed by Mesozoic strata.

Whether or not this area of Paleozoic rocks was covered over by Mesozoic strata is yet a problem. Mesozoic strata are found on two sides of the area and some is apparently structurally conformable with the Paleozoic. However, the pre-Tertiary formation had been deformed and extensively eroded before the advent of the Tertiary lavas since a well defined non-conformity exists between them. Since these pre-Tertiary formations were apparently deformed as a unit and the structural features of the same in both Mesozoic and Paleozoic, the problem of superimposition by Mesozoic strata is annulled and becomes a problem of correlating the stream pattern with lines of structural weakness.

3. Consequent drainage down the flanks of an anticline.

The line of most rapid descent of water from an anticline is natural down the sides. These four streams which cut entirely across the structure may have originally developed down the flanks of the anticline. The linear character of the streams, however, is strong evidence against this possibility, since such a stream working its way by headward erosion would be led to stray from side to side by weaker strata. That is, in a region of alternating hard and soft strata, if the stream cut through a resistant limestone stratum into a less resitant stratum, it would tend to work its way along the strike of the less resistant stratum rathern than cut through another limestone stratum beyond. However, when an anticline is formed the top stratum would offer no such conditions as alternating



A

B

FIGURE 3

hard and soft strata. The stratum would be homogeneous or at least homogeneous over fairly wide areas. Fig. 3 A and B. The streams working under these conditions would erode most rapidly where the gradient was greatest and thus cut to the crest of the anticline. The center of the anticline would then be eroded. Continued erosion might result in the capture of streams down the east flank, Fig. 4 B, by those on the west, however, there is no field evidence to date which would support such an assumption, and the linear character of the present streams could result only if the streams cutting on opposite sides of the anticline were to exactly coincide, a situation which is highly improbable. Other evidence against such a possibility would be the necessary assumption that the Paleozoic lay practically uneroded until the folding which may have occurred as late as at the close of the Triassic.

4. Superimposed by faulting

The valley of White Butte Creek shows excellent physiographic evidence of faulting, vis.:

1. Spurs faceted and aligned

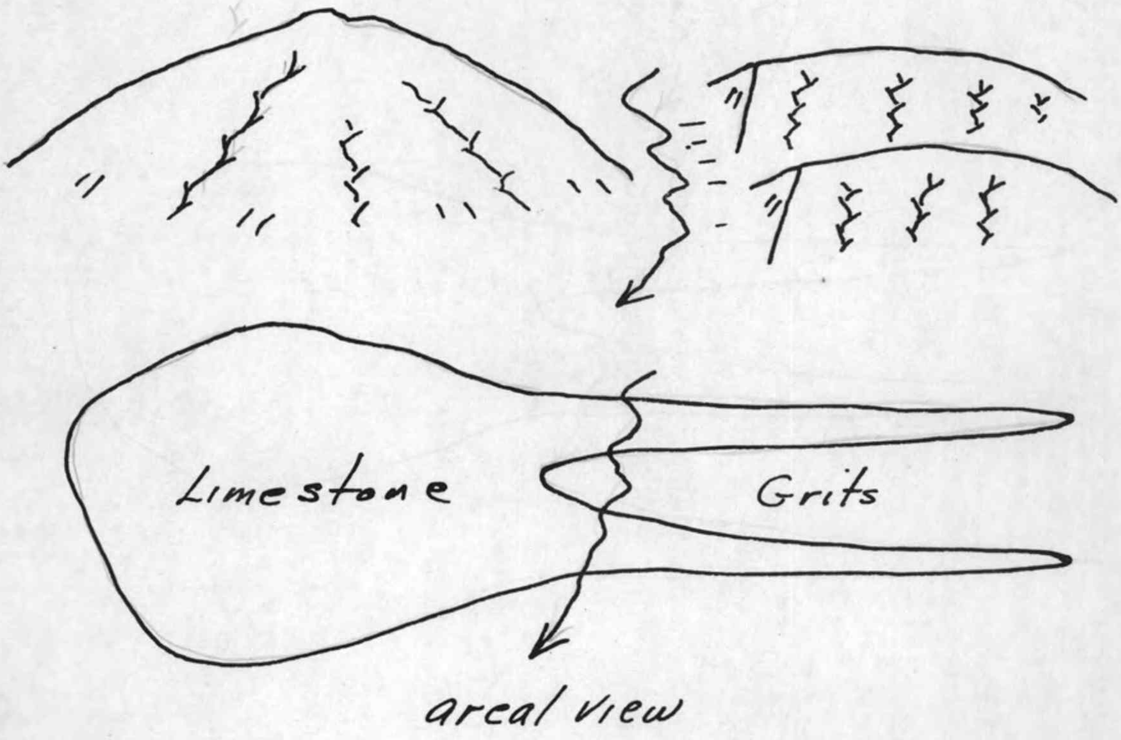
2. Valley cuts across strike of strata.

There is also some structural evidence as a large outcrop of chert near White Butte seems to have been displaced both vertically and horizontally, the displacement was not great, however, not over 200 feet horizontally or 50 feet vertically. The Tertiary lava rims on the sides of White Butte Creek do not show evidence of vertical offset. More data must be discovered before horizontal movement can be proved or disproved.

North Fork of Trout Creek shows the same physiographic evidences of faulting but no structural evidence has been noted.

Since the above mentioned physiographic evidence for faulting is fairly common throught the area it may be well to evaluate it.

Triangular facets may be produced by the truncated ends of vertical or near vertical strata in which alternating hard and soft layers weather to produce alternating ridges and valleys. If limestone beds extending from a larger mass were truncated facets on one side of a valley strongly resembling fault line facets would be developed. The facets in this area have probably been produced in this way.



The straightness of the valleys are as readily explained as being developed along jointing planes. Therefore, physiographic evidence of faulting which is unaccompanied by structural evidence should be looked upon with suspicion.

5. Superimposition by jointing

Streams developing along lines of weakness due to jointing would tend to follow the trend of the jointing.

When the stream pattern is superimposed upon a map showing the main system of jointing, the two streams in the northern part, White Butte Creek and Little Trout Creek coincide in direction to the jointing system which trends N 45° W. The two streams in the southern part, Grindstone and Twelve Mile Creeks coincide with the east-west jointing system.

As a result of this evidence it seems very probable that the master streams are controlled by the jointing and are consequent streams, whose courses have been determined by the lines of weakness. Pre-Tertiary faulting probably along a jointing plane may have played a part in the development of White Butte Creek.

The tributaries of these master streams are without exception intermittant streams. They have developed almost at right angles to the master streams as a result of erosion of the mechanical sediments interbedded in the limestones. The streams are cutting in mechanical sediments and the divides between the streams are limestone. Since these streams developed subsequent to the master streams and are controlled by the structure and stratigraphy they are classed as subsequent streams.

III STRUCTURE

A. General

The first reference to the structure of the Suplee Paleozoic was by Earl L. Packard in which he says, "The most extensive section now known is obtainable across a well defined Paleozoic anticline trending southwest from near Suplee."[1]

Further field work substantiates this earlier observation since the Paleozoic is seen to occur as an elongated anticline approximately 10 miles in length and with a maximum exposure of six miles in width. The whole structure has been eroded and the only structural evidence of the anticline remaining is the opposing dips.

The structure is covered on the south and west by Tertiary lavas and on the north by Triassic and Tertiary. In the central part of the area both limbs of the anticline are exposed where as in the northern section the exposures are predominantly of the eastern limb only a narrow strip of the western flank remaining uncovered by the lavas. Exposures of the eastern limb are also predominant in the southern section.

B. Evidence for anticlinal structure

That the structure of this series is anticlinal may be concluded from the following field evidence:

1. Opposing dips in the Paleozoic strata
2. Presence of younger (Mesozoic) strata on the flanks of the older (Paleozoic)
3. Opposing dips in younger strata, determined to be

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[1] Packard, E.L. Paleozoic and Mesozoic rocks in Central Oregon. Amer. Jour. Sci. 1928, p. 222.

younger by faunal evidence.

4. Faunal evidence within the formation.

The dips and strikes have been determined or checked by the following methods:

1. Alternation of strata of limestone and mechanical sediments elongated in a north-south direction or component of this direction indicate the direction of the strike.

2. Strikes determined a long series of outcrops indicate the same directions of strike.

3. Bedding planes show direction of dip.

4. Orientation of flattened boulders and pebbles in conglomerates.

5. Orientation of organisms in which the assumption is made that an organism such as a brachiopod which has one elongated dimension, or a flat side will lie with its flat side parallel to the bedding rather "stand on its head."

6. Character of the topography with specific attention to slopes of divides.

C. Folding

The dips of the strata are high, ranging from 45 degrees to vertical and in general the dips on the eastern flank are greater than those on the western, thus forming an asymetrical anticline, the average dip for the eastern limb is about 65 degrees while that of the western limb is about 45 degrees.

The crest of the anticline appears to pass along an area of interdigilating limestones and mechanical sediments since the western limb is dominantly grit in the northern and central part, with a few limestone lenses coming in as the axis of the anticline is approached, and also in the southern part, and the eastern limb is dominantly limestone with interbedded grits and conglomerates in the northern and central parts with grits increasing in abundance in the southern section.

Westward dipping limestone

The axis of the anticline shows evidence of deformation due to longitudinal thrusting from the north and south, the axis of warping are so spaced that they divide the anticline into three approximately

Diagram illustrating the relationship

of the drainage to the jointing system.

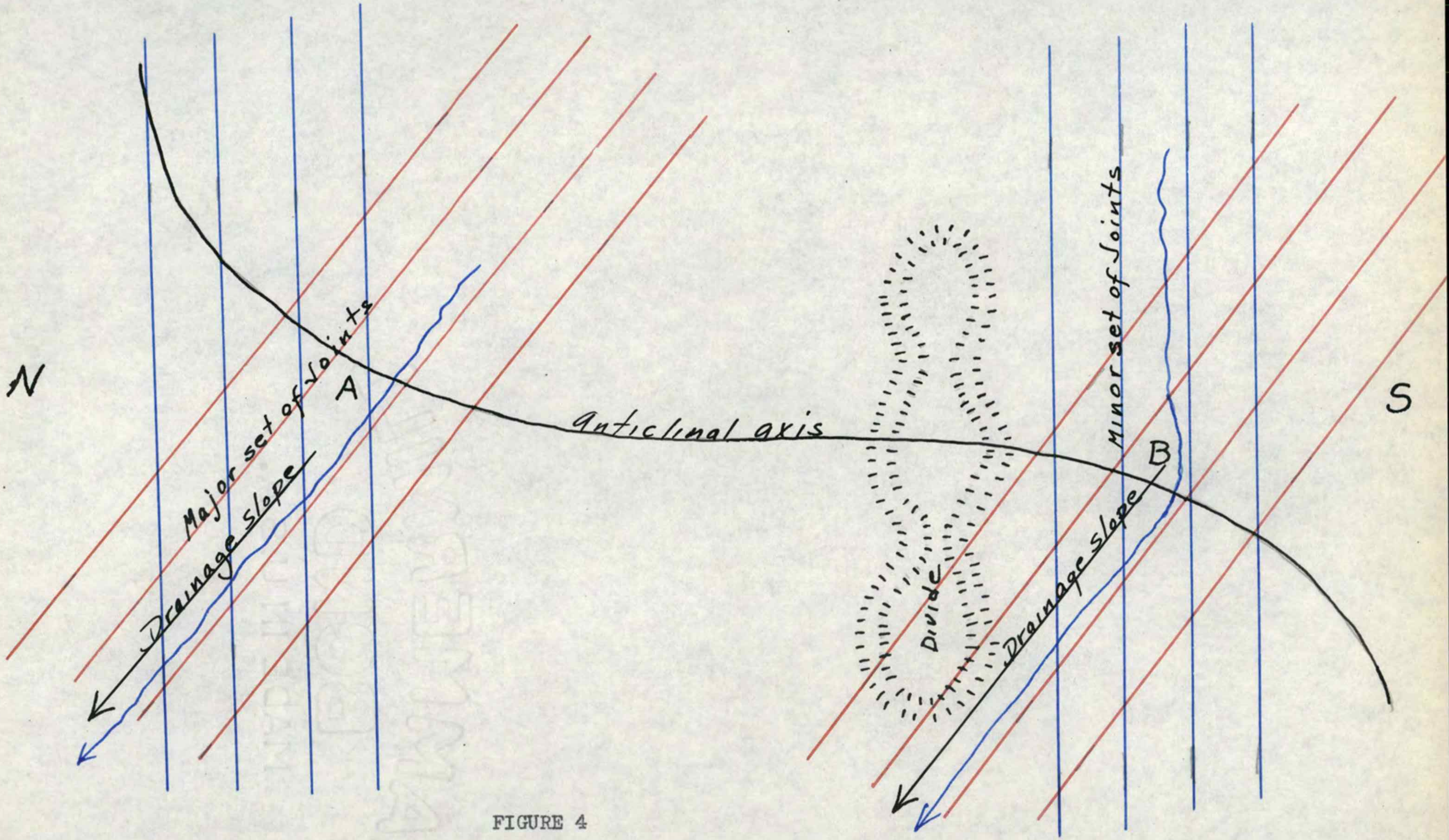
N
S
A
B
Major set of Joints
Minor set of Joints
Drainage slope
Drainage slope
anticlinal axis
Divide

FIGURE 4

equal sectors. The deformation is such that the crest of the anticline forms a symmetrical reverse curve. Fig. 4.

Tucker Buttes and South Bucher Butte represent the eastward dipping limb of the anticline in the southern section. The strike of South Bucher Butte is N 45° E with a dip of 81 degrees SE. The strike on Tucker Butte is N 50° E with a dip of 80-85 degrees SE. In the south east quarter of S 5, T 19 S, R 25 E limestone is exposed which strikes N 5° E with a high angle of dip 80-85 degrees E. Midway between this crop and Tucker Buttes is a small crop of limestone striking N 20° E and dipping 70 degrees SE. These crops bear evidence to a deformation which changed the strike of the limestone from an approximately north-south direction to a northeast direction.

The deformation is very conspicuous on the west flank in the vicinity of Mills' Sheep Corrals S 30, T 18 S, R 25 E. The strike on the series of thick grits changes abruptly from N 37° E to due north or north 10° W.

The deformation in the northern section begins in the vicinity of White Butte. Evidence of the deformation is not so abundant since the formations are usually massive and the bedding planes obscure. However, the following field evidence indicates the abrupt change in the strike from north to N 40-50° E.

1. The general trend of the limestone crops.
2. The direction of the subsequent drainage.
3. On the north extremity of a north striking ridge east of White Butte the strike changes to N 55° E striking to the SE of Point 28 and thus lining up with the limestone crops on the southeast slope of Point 28.

This strike continues with slight change until the anticline passes beneath the Triassic southwest of Suplee.

In the central section of the area the strike varies from N 10° E to N 10° W. The stike ridges forming prominent topographic features.

D. <u>Relationship to older formations</u>

No formations older than the one under consideration have been observed. Consequently the relationship between the underlying strata is as yet unknown.

E. <u>Relationship to younger formations</u>

In the northeastern margin of the area the Paleozoic is overlain by a Triassic basal conglomerate[1]; the contact is apparently structurally conformable although a hiatus must occur between the two series.

Farther south along the eastern border of the area Jurassic sediments occur folded into an approximately east-west striking anticline and syncline. This series apparently strikes directly into the north-south striking Paleozoic strata.

Under normal conditions the strata which is cut off by another is the older of the two, in this case, however, the younger of the two series is cut off by the older. This is an abnormal condition and has an explanation as presented above in faulting. The Jurassic sediments have apparently been faulted placing them in angular contact with the Paleozoic.

No Triassic strata have been recognized on the western margin of

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1 Schenck. Stratigraphy and paleontology of the Triassic of the Suplee region of Central Oregon. Master's thesis, U. or O. 1931.

the Paleozoic although sediments yielding Jurassic fossils have been discovered. These sediments are apparently structurally conformable with the Paleozoic grits although there is as yet some question as to the exact relationship. However, of the Paleozoic rocks in other parts of the state A.N. Winchell says, "The Paleozoic rocks are apparently structurally conformable with both the older formations and the more recent, but there seems to be a hiatus in deposition both before and after the period."[1]

F. Jointing.

A complex series of joints is everywhere apparent throughout the region. The limestones in some parts being badly brecciated due to the joints which strike in almost all points of the compass. The relationship of these joints to the structural movements requires a more detailed study; however, a few general facts have been observed which may have a direct bearing upon the physiography and may have resulted from the main deformational stresses.

The more prominent or master joints are observed to be concentrated along a northwest-southeast direction across the area. There are others striking northeast and some striking east and west but the greater part of them are characterized by the northwest strike. These joints are particularly prominent in the southern section. Their development in the mechanical sediments of the eastern part of this region is so great that they may be mistaken for the strike of the beds if sufficient caution is not used.

This sytem of joints may have resulted from the longitudinal

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[1] Winchell, A.N. O.B.M. & C. Vol. I, No. 5, p. 36.

deformation of the anticline. They may have developed as tension joints along the points of maximum curvature of the anticlinal axis. Fig. 4. This system of joints may have been a very cogent factor in the development of the drainage pattern of the master streams, especially in the northern part of the area. The master streams in the southern part of the area are not controlled by these prominent joints but are possibly controlled by an east-west trending series. The northwest trending joints are more prominent and the question may be raised as to why the streams should be developed along the minor joints in this section and along the major joints in the northern section. This may be tentatively answered by the fact that the general slope of the drainage of the whole area is west or northwest, or some other west component, but not in an easterly direction. Therefore the tendency of the drainage would be to follow those joints whose direction more nearly corresponded to the slope. Those in the northern part have developed on the curvature of the anticline at A on Fig. 4, and consequently had originally a northwesterly direction. Those streams in the southern part which developed down the sides of the anticline on the inside of the curve, point B Fig. 4, could not take a north-westerly direction because of the presence of a divide passing in an east-west direction across the central part of the anticline. The streams consequently must flow parallel to this divide until they could flow around it, and as a result entrenched themselves in the east-west joints which produced zones of weakness along the direction of their course.

G. Faulting

Conclusive evidence for extensive faulting within the Paleozoic area has yet to be found. The limestones show numerous evidences of small movements which resulted in the formation of slickensides. The displacement along these faces, however, is in no case more than a few feet and in most cases the amount of movement cannot be determined.

In the canyon of Grindstone Creek near Lunch Rock some evidence of faulting may be obtained. A conglomerate on the floor of the canyon east of Lunch Rock contains numerous boulders and pebbles of non-fossiliferous limestone. The structure of this conglomerate is obscure. The conglomerate does not seem to be an interbed in the Paleozoic limestones but its exact relationship is unknown.

The counterpart of this conglomerate may be found on the south side of Grindstone Creek canyon about 400 yards west and approximately 100 feet higher up the wall of the canyon.

The conglomerates are unusual and do not resemble other conglomerates in the area because they contain limestone boulders. Since they are unusual and may thus be identified the occurrence of the two crops at a distance apart may constitute evidence of faulting both horizontally and vertically, however, to be certain of this the two crops must be proven to have once been a continuous bed. Evidence for this is as yet lacking.

Approximately the same situation occurs in the canyon of White Butte Creek near White Butte. A large outcrop of cherts seems to have been displaced both vertically and horizontally, however, since outcrops of chert are fairly common and also pinch out within short distances, there is no conclusive evidence that the two outcrops are parts of a once continuous lens of chert. These observations must, therefore, be regarded as being purely preliminary and the establishment of fault lines along these valleys must await more detailed work.

Work of this kind will be particularly difficult due to the lack of consistency in the beds. They appear to change their character at random.

IV STRATIGRAPHY

A. General statement

The rocks of the area include four main types:

Limestones	38%
Mechanical sediments	50%
Cherts	10%
Igneous	2%

The limestones and mechanical sediments occur as interbedded lenses, the transition from limestone to grit or conglomerate taking place laterally as well as vertically in the section.

The cherts occur mainly associated with the limestones although they are not strictly confined to them.

The mechanical sediments may be divided into three types:

1. Conglomerates composed of rounded constituents
2. Conglomerates composed of angular particles
3. Coarse sandstone or grit composed of a high percentage of subangular particles.

The igneous rocks occur as dikes and are, therefore, post Paleozoic.

B. Limestones

1. General description

The limestones vary from a light colored crystalline variety to a dark compact impalpable variety having a semi-conchoidal fracture. They also vary from types which are extremely fossiliferous to those that are apparently barren of fossils. Some of the limestones are composed almost entirely of crinoid stems, the stems occasionally attaining a diameter of four centimeters. Other limestones contain high percentages of brachiopod shells, mainly productids, while others consist mainly of corals, foraminifera or bryozoans.

The limestones on the whole are very resistant and together with the cherts form the prominent points of the area.

They are generally brecciated or badly jointed, the numerous jointing planes breaking them up so as to produce in some instances shear-rhombs. In some cases the joints have been filled by secondary calcite.

In places the limestones contain considerable detrital material, thus forming an arenaceous limestone. The detrital material may gradually increase so that the limestone grades into a sandstone having a calcareous cement. Thus every gradation from pure limestone through gritty or arenaceous limestone to calcareous grits or sandstones and standstones having a calcareous cement has been noted.

Chert lenses, nodules and beds are common within the limestones, and weathering of these cherty limestones leaves the surface covered with angular chert fragments.

The limestones weather to light gray or white. Some of them are densely black on the fresh surface and white on the weathered surface, the difference in color possibly being due to oxidation of included carbonaceous material.

2. Microscopic description

Some of the limestones are seen under the microscope to be made up of the shells of organisms, foraminifera and bryozoans being common. Patches of crystalline calcite occur throughout. Other limestones are made up entirely of crystalline calcite with an occasional small streak of dolomite. The dolomite, however, is rare.

3. Occurrence

The limestones occur most abundantly on the eastern flank of the anticline, but in the southern part of the area occur on the western flank. The limestones occur as lenses inter-bedded with the coarse mechanical sediments and it is noticeable that they pinch out suddenly along the strike, giving way to rather large areas of mechanical sediments in which very little limestone occurs.

This very definite inter-bedding of the limestones with the coarse sandstones, grits, and conglomerates, and the apparent absence of finer textured sediments such as shales, together with the extreme variability of the strata present a setup which indicates unusual conditions of deposition.

In numerous instances the limestones are massive, an entire hill being formed of a single mass. The bedding is obscure and sometimes apparently entirely lacking.

Some of the limestones, however, occur as lenses apparently very thick for their lateral extent; these have a somewhat similar occurrence to the limestones of Paleozoic age in southern Oregon, which according to Winchell[1] "...do not seem to be of proper shape to represent coral reefs, and it seems quite improbable that pure

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[1] Winchell, A.N. O.B.M. and G. Vol. 1, No. 5.

limestone should be deposited in such small areas while mud and sand formed all around it. Mr. L.E. Reber has suggested that the lenses of each belt once formed a continuous belt about 150 feet thick which was sliced diagonally during great tectonic movements along many planes about 500 to 600 feet apart, the fragments of the beds were then separated by rock flowage and possibly by horizontal faulting during prolonged and important earth movements."

This explanation would be satisfactory for the Suplee region provided the evidence of faulting could be produced, but the shape of the limestone lenses is at best only meager evidence of such great tectonic movements as Reber suggested.

Carwood[1] describes knoll reefs which "often form small dome-like eminences composed of highly fossiliferous crystalline limestone containing a special fauna of brachiopoda, millusca or bryozoa. They are evidently of shallow water origin and contain sheets of calcareous tufa..... the bedding is often obscure, the surface layers may show a quaquaversal dip and contemporaneous breccias are locally conspicuous." This description suggests a possible origin for the lenses of Suplee limestone. The limestones do not generally have the appearance of reef origin but several occurrences, especially in the northern part of the area, particularly Point 28, S 3, T 18 S, R 25 E have several characteristics of reefs, in that these are conposed almost entirely of special faunas of calcareous organisms, and are massive, showing little or no bedding.

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1 Carwood, E.J. Handbook of the geology of Great Britain - Lower Carboniferous. P. 181.

Diagram illustrating manner in which part of the Paleozoic sediments were deposited.

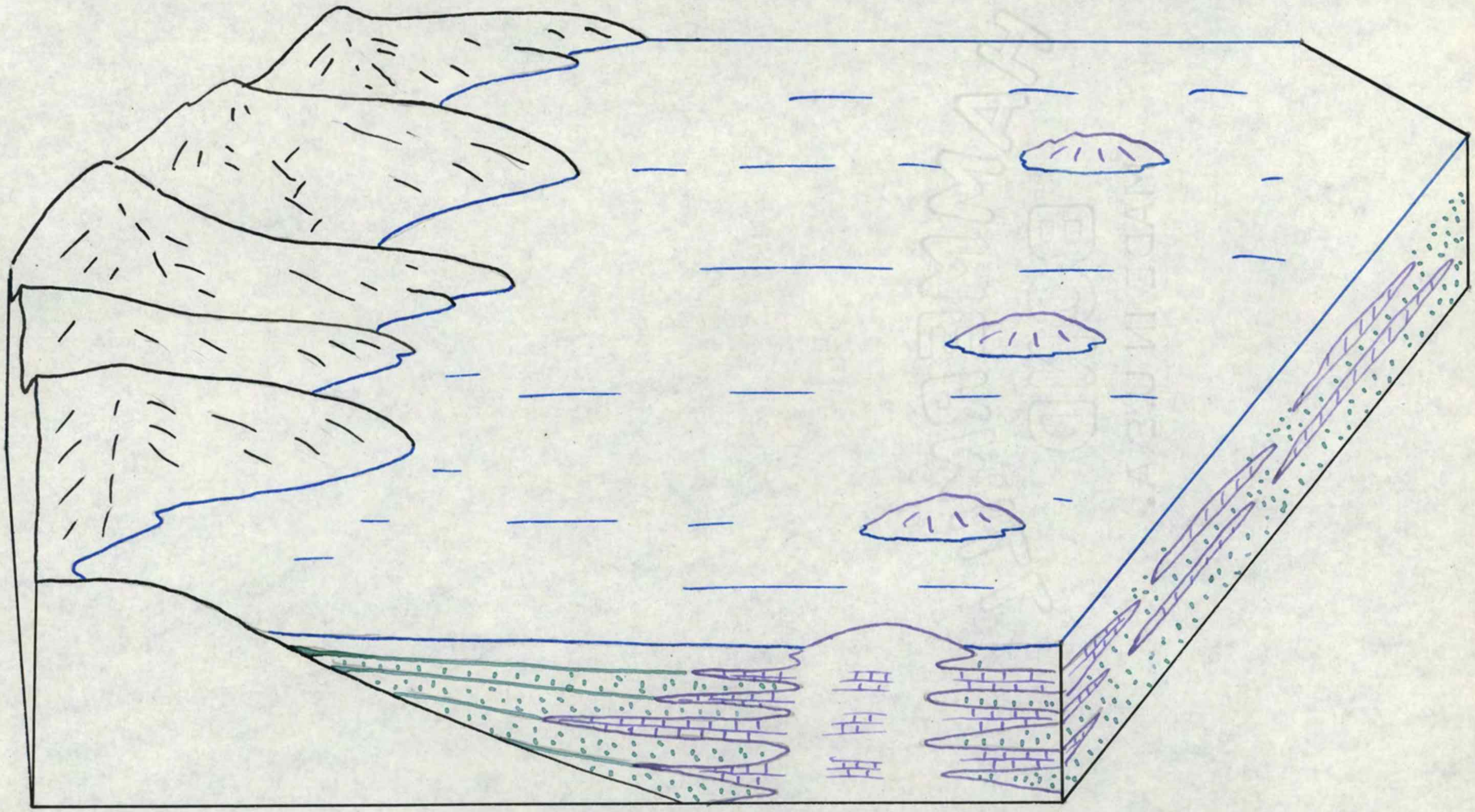
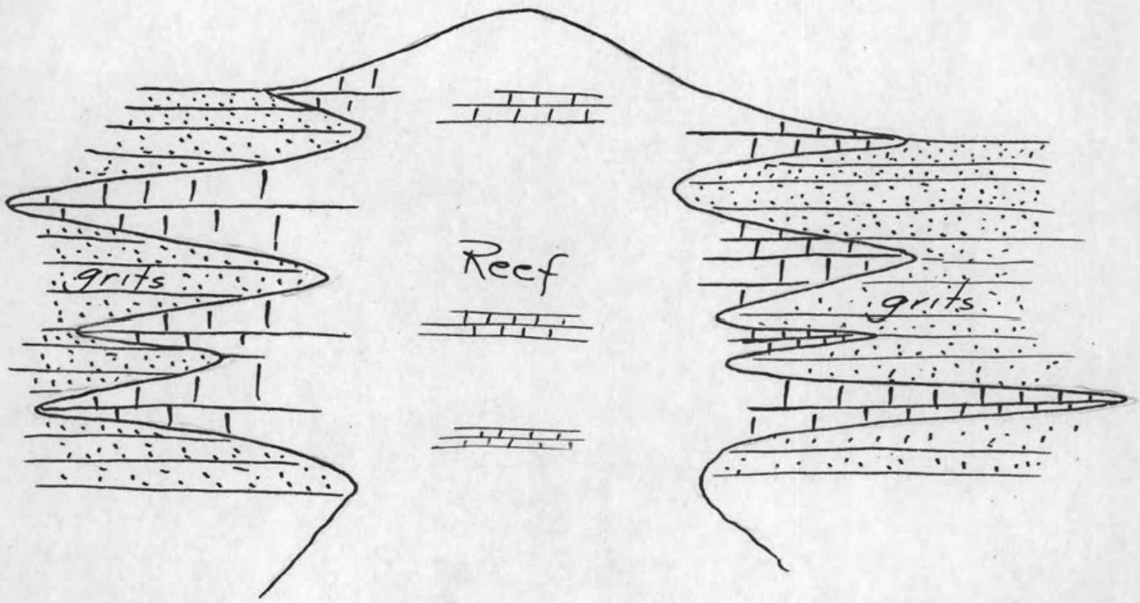


FIGURE 5

The lenses are interbedded with mechanical sediments of a texture not finer than a sandstone. This occurrence with the absence of shales or calcareous muds possibly indicates a condition in which the coarse mechanical sediments were periodically dumped into the sea. If reefs were growing in the shallow water near the margin of the land, detrital material from the reefs together with calcium carbonate precipitated due to excessive concentration near the reefs would accumulate for a time and be periodically covered over or interfingered with the mechanical sediments from the land mass. Fig. 5. This would account for the fact that some of the limestones are bedded while others are not, it would also account for the extreme variability and the inter-bedding of the limestones and mechanical sediments and for the thinning out of the limestone beds which were very thick in the center, since the lens effect would be due to the thinning out of the beds on the sides of the reef and the thickness of the bed in the center would be due to the main mass of the reef itself. Furthermore, this setup would explain why limestones suddenly cease and grade into great thicknesses of mechanical sediments, in which limestones do not occur possibly because no reefs were growing in that particular locality and were deposited too close to shore for calcium carbonate to be chemically precipitated.

4. Origin

Some of the limestones appear to be of reef origin being massive in form and occurrence and containing great quantities of fossil organic remains, such as crinoid stems, brachiopods, corals, foraminifera and bryozoans and possibly calcareous algae. Other bedded limestones may owe their origin to accumulations of calcareous material weathered from reefs and to the precipitation of calcium carbonate caused by local concentration near the reefs. Others may be due to chemical precipitation of calcium carbonate carried to the sea by streams.



C. Sandstones and grits

1. General description

The color of the sandstones or grits as they may be well called, varies from gray to brown depending upon the composition of the constituent particles.

The bedding is always well developed and distinct in these sediments, the best and consequently the most reliable strikes and dips in the area are obtainable from the outcrops of the grits.

Sorting of the constituent particles is very little in evidence. The various sizes are mingles together, ranging from. 5mm. to .5cm with the average size about 1 mm. The constituent fragments are mostly of angular outline; less than ten per cent show evidence of rounding beyond the subangular stage.

The constituent particles of the grits are about 90% chert with 10% feldspar with an occasional grain of augite. The cement is calcareous.

2. Age and relationships

The high percentage of chert fragments in the mechanical sediments may cause some doubt as to whether their age should be placed as the same as that of the limestones. The argument being that the cherts contained in the mechanical sediments were probably derived from the Paleozoic cherts, and consequently must be of later age. However, the following facts are cited as evidence that such is not the case and that these mechanical sediments are more probably the same age as the limestones. (1) In the Mesozoic formation which contain angular fragments of chert derived from the Paleozoic, there are also associated limestone boulders and fragments.[1] In some cases these limestone fragments contain Paleozoic fossils proving conclusively that they were derived from the Paleozoic formations. In the examination of the mechanical sediments under consideration in this paper, no associated limestones were found, cherts alone are the primary constituent. The question may then be asked, If these chert-bearing mechanical sediments are younger than

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[1] Personal communication with Dr. E.L. Packard.

the Paleozoic limestones, why are the Paleozoic limestones always absent from these sediments? Very likely the cherts from which these sediments were derived were not associated with Paleozoic limestone, or any limestones. (2) The presence of the cherts associated with boulders and pebbles of granular igneous rocks the counterpart of which are not found outcropping in the area suggests that the cherts were derived from some land mass which also contained granular igneous rocks. Since the following evidence points to contemporaneity of origin for limestone and mechanical sediments the assumption is that such a land mass must be older rather than younger. (3) Apparent interbedding of limestone and lenses of mechanical sediments. There is a definite gradation from pure limestone through gritty limestone, through calcareous grit to a grit having a calcareous cement. (4) Limestone thins out along its strike and gives way to mechanical sediments. (5) There is a correspondence in structure of the two materials. The strike and dip of a limestone lens surrounded by mechanical sediment always corresponds to the strike and dip of the mechanical sediments and vice versa. (6) The two have been deformed as a unit as shown by abrupt changes in strike. (7) The mechanical sediments are cemented by calcium carbonate. The only exceptions to this have been noted and an explanation given above.

As a result of this evidence, the age of the mechanical sediments is concluded to be of the same age as the limestones and interbedded with them.

3. Occurrence and origin

The sandstones and grits occur most abundantly in the west central and east southern portion of the area. A large mass of well bedded sediments occurring on the western flank of the anticline west of the Productus Giganteous locality, central part S 30, T 18 S. R 25 E, on the eastern flank of a large mass of sediments occurs between Grindstone and Twelve Mile Creeks. The bedding in these sediments is well developed and a single bed may be traced entirely across the mass where it gives way to limestone wholly or partially. However, these areas of sediments are apparently as thick as they are long, thus indicating an unusual manner of deposition. From the excellency of the beds and the ease with which the individual beds are traced it would be expected, if the beds were of marine origin, that they would have a great lateral distribution. However, the coarseness of the constituent particles together with their limited aerial extent indicated that they may be delta deposits or rivers which carried enormous quantities of detrital material at definite intervals, this interval being indicated by the interbedding of the limestones lenses, since obviously some time must be required for the bedded limestones to accumulate. Twenhofel[1] states that "During past geologic ages when shallow seas covered vast areas of the continents and highland regions bordered the seas, ideal conditions existed for the development of large deltas. If the regions of supply of sediments are being elevated and the sites of delta deposition were sinking great thickness of delta deposit would be possible. That this has occurred during several periods of geologic

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[1] Twenhofel, W.H. Treatise on sedimentation, p. 848.

time is certain."

Part of this material was no doubt distributed laterally along the shore by the shore currents and was mixed with the marine sediments being deposited at the time.

D. Conglomerates

The conglomerates are of two types, (1) Those composed of rounded particles, (2) those composed of angular particles. These will be considered in the order named.

1. General description and occurrence

The conglomerates are massive and the structure is usually obscure although the orientation of flattened boulders indicates the general direction of dip. From this method of determination the conglomerates appear to coincide with the limestones in strike and dip.

These conglomerates are composed of particles ranging in size from 1 cm. to 50 cm. and in some instances the larger boulders are distinctly flattened, the ratio being generally about 2:;, that is, the boulder is about twice as wide or long as it is thick. The flattened boulders are not characteristic of the conglomerates, however, since there are several occurrences in which the flattened boulders are not conspicuous.

Conglomerates occur most abundantly in the center of the anticline. Well defined outcrops occurring east of Productus Giganteous locality and on both sides of the valley formed by the erosion of the crest.

This conglomerate is apparently about 80 feet in thickness and grades from west to east, i.e. from top to bottom of the bed from pebbles about 5 cm. in diameter to cobbles or boulders 45 cm along their greatest diameter. The boulders are generally flattened though not invariably. This conglomerate is not persistant and is apparently a boulder facie in the grits. Another crop similar to this and in a similar position stratigraphically is found in the northern part of the area at the base of Point 28, S 3, T 18 S, R 25 E. This outcrop has the same general characteristics as the one described above, with the exception that the largest cobble is 25 cm. along its greatest diameter. It also occurs as a lens and is apparently a boulder facie in the grits.

Approximately 2000 feet east of the crest of the anticline another series of conglomerate lenses occur. They have the same characteristics as the outcrops above, flattened boulders up to 30 cm. along their longest diameter and approximately two along the shortest. The lenses are apparently about 45 feet in thickness.

The next conglomerate is found in Lunch Creek canyon, S 28, T 18 S, R 25 E. This conglomerate is not persistant, but occurs in lenses approximately 30 feet in thickness and interbedded in the grits; it cannot be traced horizontally either as a bed or as a series of lenses. The boulders range up to 30 cm and are flattened; the orientation of the boulders indicating an eastward dip of the lens. The percentage of flattened boulders in this outcrop is only about half as large as in the previously described outcrops.

2. Composition

The conglomerates are composed mainly of coarse grained igneous rocks, cherts, and a dark fine grained igneous rock.

The percentage of coarse grained igneous rock is highest in those conglomerates near the center of the anticline and consequently the older. The coarse grained igneous rock make up approximately 40% of the total, chert 35% and basalt 25%.

The coarse grained igneous rocks are Potassium granite, soda granite and Gabbro. The Potassium granite has a pink orthoclase, 70%, hornblende, 10%, and quartz, 20%.

The gabbro is about equal in percentage to the other two types. Near the top of the section the cherts replace the plutonic rocks in abundance. The conglomerates composed of angular fragments occur on the west flank of the anticline west of Mills Sheep Coral, S 30, T 18 S, R 25 E, and at the base of the lava capped hill in the northern part, Central part S 4, T 18 S, R 25 E.

This conglomerate is made up largely of angular fragments of chert up to 6 cm. in diameter. Here and there, however, the chert particles show some degree of rounding; these may be classed as subangular. The brown chert make up fully 75% of the composition of the conglomerate with the red, green, black, and white varieties making up the remaining 25%; of these green is the most abundant.

3. Origin

It has been pointed out by Johnson[1] that gravel deposits of continental origin where exposed to observation are greatly elongated in the direction of the streams, i.e. the direction leading

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[1] Johnson, D.W. The high plains and their utilization. 21st An. Rept. U.S.G.S. Part IV, 1901, p. 634.

away from the source of supply. Mansfield[1] has noted that shore gravels on the contrary are extended in courses parallel to the margin of the deposit. Barrel[2] says, however, that "ancient conglomerate formations are commonly folded and tilted and it is seldom that a bed can be studied in two directions to a sufficient extent to determine the relation of the gravel strata to the direction of sedimentation." Barrel says further that "no distinction in form has been shown to exist between river and shore gravels...and that intercolated nonconglomeratic beds and the relations to the under overlying strata are frequently of high supplemental value for determining the mode of origin especially where the finer textured beds carry evidences of terrestrial origin the argument is strong that the associated coarser beds are also terrestrial. Where finer beds carry marine fossils, these contiguous coarser beds are presumably in part if not wholly marine." Further "Marine conglomerates except under local and special conditions are limited to considerably less than 100 feet in thickness. Terrestrial conglomerates are frequently measured in hundreds and occasionally thousands of feet."

Evidences of marine life in the grits in which the conglomerates are interbedded is scarce but not entirely lacking. Corals and a form which may possibly be an Orthoceras have been found in the grits. This is conclusive evidence that the marine environment was not entirely absent during the deposition of the grits.

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1 Mansfield, G.R. The characteristics of various types of conglomerates. Jour. of Geol., Vol. XV, 1907, p.554.

2 Barrel, Joseph. Criteria for the recognition of ancient delta deposits. Bul. G.S.A., Vol. 23, 1912.

The thickness of the conglomerates and their occurrence as lenses points to their being of marine origin occurring as gravel facies along the shore. The flat shape of the boulders is further evidence of this since Grabau[1] says, "On a shallow coast where the wash of the waves rushes up and down the beach as a sheet flood the pebbles are more often merely moved backward and forward without much overturning, or again the pebbles are scarcely moved but polished and worn by the sand carried back and forth across them."

Thus the thickness of the grits and sandstones together with their limited aerial extent, the presence of marine fossils in some of the grits and the general characteristics of the conglomerates such as thickness and shape of cobbles, points to a condition, where continental sediments and marine sediments mingle, or to deposition at a river mouth where continental deposits were being made on the margins of the land.

E. Cherts

1. Introduction

Definition, "In the strict sense chert includes those cryptocrystalline varieties of quartz which are white, gray or other light colors. Flint includes the dark gray or black varieties of the same material. Jasper is a variety colored red by iron oxide."[2] For the purposes of this discussion the name chert will be used to apply to all varieties since distinctions are based largely upon color and not upon the mode of origin, however, this statement is

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[1] Grabau, A.W. Principles of stratigraphy, p. 595.
[2] Twenhofel, W.H. Treatise on sedimentation, p. 519.

not to be interpreted as meaning that the color may not be a function of the mode of origin, but it is not the purpose of this discussion to establish such functional relationships.

This discussion will be concerned with localities and distribution of the cherts, the relationship of the cherts to other rocks of the area, their structural features, stratigraphic position, petrological types and characters, comparison with other occurrences and finally an attempt to establish the time relationship of the cherts to enclosing rock with suggestions as to possible origin.

2. <u>Localities and distribution</u>

The cherts are widely distributed, occurring throughout the area without apparent correlation between the various occurrences. They are mainly associated with the limestones and consequently are found in those parts of the area in which limestone occurs. The cherts appear in greatest abundance on the eastern flank of the anticline. The best localities for studying the occurrences of the cherts are (1) Iron Mountain and ridges to north, (2) Lunch Creek canyon and White Butte in S 16, T 18 S, R 25 E in the central portion of the area, (3) Point 28 and the westward dipping limestone crop in the N.W. $\frac{1}{4}$, S 34, T 17 S, R 25 E in the northern part, and (4) Bucher Butte, Point 5 and Point 11, S 8, T 19 S, R 25 E in the southern section.

3. <u>Relationship of cherts to other rocks</u>

As stated above the cherts so far as observed occur associated mainly with the limestones although the chert band on the eastern flank of the anticline is apparently lying on top of a series of mechanical sediments which grade laterally into limestones. There is apparently no consistent relationship between the limestones and the cherts, since the cherts are interbedded, intrabedded and occur cutting across the limestone beds. Isolated nodules are also common. The occurrence as large interbedded lenses seems to be a common mode.

So far as observed different colored cherts appear to have different modes of occurrence. The difference cannot be referred to a definite line of demarkation but taken as a whole the black cherts have characteristic modes of occurrence which are different from that of the brown or red cherts.

The occurrences of these different types of chert will be described in detail later with the petrological descriptions.

4. Structural and textural features

No where have any structural or textural features characteristic of the limestone been preserved by chert.

5. Stratigraphical position

Stratigraphically the cherts appear from the lowest exposures of the limestones to the highest; they are confined principally to the eastern flank of the anticline because the anticline was apparently folded at the point where the limestones and mechanical sediments interfingered. The cherts cannot be considered as concentrated near the top of the anticline but they occur in greater thicknesses as the top of the anticline is approached. A wide band extends with a few breaks entirely across the area and represents the top of the section on the eastern flank of the anticline, since it is apparently on the non-conformable contact with the Mesozoic.

6. Petrological types and modes of occurrence

a. The red and green cherts.

The red and green cherts are the least common variety occurring only infrequently as small, irregularly shaped nodules.[1] Some occur with a pure reddish brown color; others are green, still others are banded red and green, the bands varying greatly in width. The green color seems to occur more abundantly on the outer surface, while the red is more concentrated near the center. Davis[2] noted this phenomenon and interpreted it as due to reduction of iron oxide near the weathering surfaces while the red near the center was comparatively unaffected.

These cherts have a sub-vitreous luster and a sub-conchoidal fracture, the fracture planes are very irregular and the chert often breaks in such a manner that very sharp edges result.

Traversing these cherts are often minute veins of crystallized quartz, these veins cut indiscriminately across the red and green bands and appear to be epigenetic.

(1) Microscopic description. Under the microscope these red and green cherts are seen to consist of a fine grained aggregate of silica with rough bands of reddish or greenish semi-translucent substance presumably iron oxide. Dispersed throughout

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1 A hand specimen of a rock associated with the Clarno extrusives collected by W.D. Wilkinson cannot be distinguished from these cherts. Comparative thin-section studies have not been made as yet so that no information regarding their microscopic make-up is available.

2 Davis, E.F. Univ. of Calif. Bul. of Dept. of Geog., Vol. II, No. 3. Dec. 1918.

the section are small clear areas of circular or ellipsoidal outline. Some of these small areas are filled with a fine mosaic of quartz while others show an excellent dark cross, characteristic of chalcedony, under crossed nicols. No evidence of radiolarian remains were noted in these cherts, but Davis says that recrystallization may obliterate all traces of the organisms.

b. Brown cherts

The brown cherts vary from light to very dark brown. The fracture is sub-conchoidal, but these cherts also have well developed jointing or rock cleavages which produces a tendency to weather out in angular blocks; this probably is the result of cleavage or jointing developed during the deformation of the area, since the brown cherts occur usually in larger masses than the other types. It is noticeable that the larger the chert mass the more evident is the jointing. This type of chert has very evidently been formed before the deformations which caused the jointing throughout the area.

The color is unevenly distributed throughout the mass. In some localities the brown chert contains small spots and elongated and irregular masses of lighter colored material. Similar spots have been interpreted elsewhere as evidence of the existence of radiolarian in the chert. However, no actual remains of these organisms have been noted in these beds.

(1) Microscopic description. These cherts do not differ greatly from the red and green type. The round or ellipsoidal areas may be seen, some showing a dark cross under crossed nicols, others are composed of interlocking grains of quartz. No

evidence of radiolarian skeletons or sponge spicules were noted.

(2) Form and mode of occurrence. The brown cherts occur mainly as large lenses or interbeds. These lenses which vary extensively in length and width occasionally stand up as "dike" as a result of differential erosion. At other places angular fragments are strewn profusely over the surface where they have been accumulated as a result of the weathering of the limestone with which the chert is associated.

These cherts occur wherever there is limestone, but they are far more concentrated on the east flank of the anticline. On the extreme margin of the anticline a band of chert extends from near Suplee south to Iron Mountain with only an occasional break. This band is apparently not of uniform thickness but reaches its maximum at Iron Mountain where it is not less than 500 feet in thickness. It thins out to the north where it is 100 feet thick.

South of Iron Mountain this chert disappears, apparently being covered over by Mesozoic sediments, and reappears between the Flatiron locality, S 5, T 19 S, R 25 E and Tucker Buttes; it then apparently pinches out at the northwest base of Tucker Buttes. The mechanical sediments near this occurrence of chert are firmly indurated by means of a siliceous cement. The mechanical sediments invariably have calcareous cementing material except where they are closely associated with the cherts, then the cementing material is siliceous.

At White Butte, which is a large limestone hill, the limestone is seamed in all directions by the cherts. There is no apparent consistency of occurrence of the chert. It occurs as isolated nodules with irregular outlines, as lenses along the bedding, and as "veins" cutting across the bedding at every conceivable angle. These chert bands are from 1" to 18" in thickness and they have the appearance of having been intruded into the limestone. However, there is no apparent metamorphism along the contacts and a silicified coral was found imbedded within the chert. These cherts also contain spots of calcium carbonate so that a fragment when immersed in acid will effervesce at numerous places.

Much of this chert is spongy and has the aspect of a chert which contained some soluble material that had previously dissolved and weathered out; similar occurrences of chert are noted in the Carboniferous.

"Great quantities of chert are left as a residue on the surface, by the solution of limestone by the ground water. From the chert itself is removed whatever calcium carbonate it originally contained together with more or less of its silica so that much of it is porous and spongy though a great deal still remains compact."[1]

Isolated residual boulders of chert having smaller particles of limestone included along the margin have been found, the contact between the chert and limestone is always very irregular, chert stringers extending into the main body of the limestone and vice versa. These boulders have evidently weathered from larger masses and represent a part of the contact between the chert and the limestone.

A bed of coarse sandstone which occurs on the east side of White Butte has become so impregnated by silica that it appears to

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[1] U.S.G.S. Folio 202, page 10.

be composed entirely of silica; only under close inspection is its real nature apparent.

c. Black cherts

These cherts are dark in color grading from a blue-black to black. They have the typical sub-conchoidal fracture but the parting surface is somewhat rougher suggesting that these cherts are not so impalpable as some of the varieties. Small spots of white chert occur associated with the black variety--perhaps due to the leaching of the carbonaceous material in the darker cherts.

(1) Microscopic description. These cherts appear to be composed of interlocking grains of cryplocrystalline silica which makes up a fine mosaic. No amorphous silica was noted. The clear areas of chalcedonic silica also are conspicuously absent.

(2) Form and mode of occurrence. The black cherts occur as nodules and as beds in the limestones. At three localities (1) Hill north of Crinoid reef, (2) on the west wall of Lunch Creek canyon, about $\frac{1}{4}$ mile up the canyon, (3) on the west slope of Bucher Butte, the cherts occur in distinct beds alternating with beds of limestone. The beds of chert are approximately 1" to 6" in thickness and are separated by beds of limestone of approximately the same thickness. Well preserved fossils have been found in these cherts.

The contact between the limestone and chert is apparently a sharp one in hand specimens, but under the microscope as described by Twenhofel:

"The chert is intergrown with the limestone in an exceedingly intricate and labyrinthine way."[1]

Small stringers extend from the limestone out into the chert and isolated particles of calcite are seen entirely surrounded by chert. This is sometimes used as evidence of replacement i.e., that the remnants represent unreplaced remnants of the surrounding rock, "but these areas are as readily explained as being due to the inclusions of calcareous materials in the chert during its accumulation, or as being the result of the aggregation of both the calcium carbonate in the gel and that which had migrated into it. The migration of such salts in gels is a common phenomena."[2]

7. Theories of chert origin

a. General consideration

Theories of chert origin must stand or fall by the testimony of the field relationships, occurrences, and general characteristics of the chert. The various occurrences of the Suplee cherts have been enumerated and the significant ones will be summarized below.

It will now be the purpose of this discussion to present the main theories of chert origin together with such evidence for or against each theory as is to be obtained from field evidences. After this presentation an effort will be made to explain the origin of the Suplee cherts in the light of one of the theories.

In order that a theory be applicable to the origin of the

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1 Twenhofel, W.H. The chert of the Wreford and Foraker limestone. Amer. Jour. Sci., Vol. 47, 1919, p. 407-429.

2 Ibid., p. 535.

Suplee cherts it must explain certain field relationships and occurrences which are here presented in a summarized form.

b. Occurrences and relationships which theories of origin must explain

(1) Silicified fossils within the chert

(2) Rhythmic alternation of beds of limestone and chert

(3) Large lenses of chert near top of section, not always association with limestone

(4) Lenses of chert not associated with structural features of the limestone

(5) The siliceous cement of the sandstone in specific localities

(6) Irregular shaped nodules

(7) Intricate network of chert cutting some limestones

(8) Isolated patches of limestone in the cherts

(9) The very irregular contacts between chert and limestone

(10) Occurrence of chert in the Triassic sediments--thus limiting the time of formation of the cherts

(11) Cherts found in crystalline limestone do not have the crystalline form of the calcite

(12) Weathering produces a porous mass of chert

(13) A coral found in the cherts was not entirely silicified.

c. Time relations and origins

According to Twenhofel the time relations of the chert to the enclosing rock may be divided into three groups.

A. Formed after the consolidation of the enclosing rock - epigenetic origin.

B. Formed contemporaneously with the accumulation of the materials of the enclosing rock - syngenetic origin.

C. Formed pene-contemporaneously with the accumulation of the material of the enclosing rock. Syngenetic origin. He says further that for chert or flint to be of epigenetic origin it must either replace the original rock or fill cavities therein.[1]

d. Theories of epigenetic origin

(1) Replacement

(a) Evidences for replacement. The theory of replacement is generally considered as the most important method of epigenetic origin. Ground waters carrying silica in solution permeates the limestone and part or all of the calcium carbonate is replaced molecule by molecule by the silica. To be strictly epigenetic the replacement must take place after the limestone has become indurated. The evidences for replacement are as follows:[2]

1. Occurrences of chert along fissures in limestone
2. Very irregular shape of the chert nodules
3. Presence of irregular patches of limestone in some chert masses
4. Association of silicified fossils and chert in some limestone
5. Presence of replaced fossils in chert
6. Preservation of structures and textures of limestones in some cherts
7. The failure of cherts to follow definite zones in limestone formations

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1 Twenhofel, W.H. Treatise on sedimentation.
2 Van Tuyl, F.M. Origin of chert. Amer. Jour. Sci, Vol. 45, 1918, p. 449-56.

8. The occurrence of silicified orlites formed by the replacement of calcareous ones.

9. Retention in chert of markings in the limestone including grain, stratification, styolites, is valid evidence of secondary character.

10. Bowing of beds irrefutable evidence in favor of epigenetic origin.[1]

11. Uneven growth of the chert.

Of these evidences for replacement the following are applicable to the Suplee cherts. However, these occurrences and relationships are largely confined to one locality, vis. White Butte, S 16, T 18 S, R 25 E.

Irregular shaped nodules
Presence of irregular patches in some chert masses
Presence of replaced fossils in chert
Failure of cherts to follow definite zones in limestone formations.

(b) Evidences against replacement.

Evidences as given by Tarr[2]:

1. Uniform distribution of chert along planes in limestone and absence of structural control of these planes of chert.

2. The impermeability of limestones.

3. Absence of source of silica in limestones or adjacent rocks.

4. Deposition of chert does not occur in the main solution channels in limestone.

5. No structural features in limestone preserved by chert.

6. The occurrence of angular brecciated fragments of

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1 Dean, R.S. Formation of Missouri cherts. Amer. Jour. Sci., Vol. 45, 1918, p. 411-14.

2 Tarr, The origin of chert in Burlington limestone. Amer. Jour. Sci. Vol. 44, 1917, p. 409-51.

chert in larger masses of chert.

7. The cracks in the chert and their filling of limestone are not due to replacement.

8. Banding or mottling of chert not due to replacement for such structures are not developed by replacement.

9. Fossils in chert too well preserved to be residuals from replaced limestone.

10. Weathering produces a porous (where fossiliferous) fragments more or less decomposed chert.

11. No evidence of growth at present time or since period of deposition of limestone.

12. Presence of chert in conglomerate at the base of formations exactly like the chert in underlying formations.

13. Silica content of cherty formations very low.

14. If the fossils held in the cherts are of better preservation than those in the limestone it should be considered positive evidence that the chert is not a replacement of the limestone.[1]

15. Colloidal silica is a solid particle and thus cannot migrate through solid limestone or dolomite and as much chert and flint occur within a bed such migration would be essential if chert were epigenetic in origin.

16. If cherts were epigenetic it would seem probable that chert bands would show some tendency to cut across stratification.[2]

17. The rhythmic alternation of limestones and bedded cherts would be difficultly explained by the replacement theory.

Many of the above objections to the replacement theory will be seen to apply to the Suplee cherts especially when the cherts at Iron Mountain SE $\frac{1}{4}$ S 34, T 17 S, R 25 E, those in Lunch Creek Canyon SE $\frac{1}{4}$, S 28, T 18 S, R 25 E and those on Bucher Buttes

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[1] Twenhofel, W.H. Amer. Jour. Sci. Vol. 47.

[2] Barton, D.C. Notes on the Mississippian cherts of St. Louis Area. Jour. of Geol. Vol. 26. 1913. pp 361-74.

are considered.

The most important objections to replacement at the above localities are:

1. Rhythmic interbedding of chert and limestone.

2. No preservation of structural or textural features of the limestones by chert.

3. No tendency to cut across stratification.

4. No evidence of growth at the present time.

5. Presence of chert in basal Triassic beds associated with Paleozoic fossils proving the cherts to be the same as that now associated with the limestone.

6. If ground water carried enough silica to cause the limestone to be replaced by it on such a large scale, why did the silica not replace the calcareous cement which indurates the mechanical sediments interbedded with the limestones?

Only in a few specific localities is the cementing material in the mechanical sediments of silica while the chert in the limestone is very widespread. An explanation of this will be given later.

One other theory favoring the epigenetic origin of the cherts is that proposed by Ulrich & Bain[1] wherein the chert is assumed to be the result of silica concentration during the process of weathering. Woodward[2] also presents this theory and gives the following evidence in favor of it:

1. Cherts prevailingly abundant upon the weathered exposures and residual soils of certain formations but conspicuously absent in the fresh bed rock of the same formations.

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[1] Ulrich, E.D. & Bain, F.H. The copper deposits of Missouri. Bul. U.S.G.S. 267, 1905, p. 27-30.

[2] Woodward, H.P. Paleozoic cherts of west central Virginia. Jour. of Geol. Vol. 39, 1931, p. 277-98.

2. Cherts not appearing to be characteristic of any given horizon but favoring certain definite types of topographic expression in the formation.

3. The chert which is known to occur in bed-rock generally occurs near the top of the formation which in most cases means that the cherty lenses occur directly below an unconformity or old denudation surface.

4. Finding cherty ledges and masses at the surface grading downward into unsilicified calcareous bed-rock below. This is also true on a smaller scale of many of the fossils which are silicified on the surface but are calcareous within.

5. The majority of the cherts have the same general structure as the enclosing rock and if they are in lenses these lenses conform to the bedding planes of the rock.

6. The cherts show a strong tendency to appear at similar elevations throughout any local area and to be absent at elevations above or below this zone of concentration.

Because of these observations Woodward believes the cherts (at the locality studied by him) to be epigenetic. He concludes as follows, "It would further seem probable that the development of the chert is a function of surfacial weathering since so great a proportion of the chert is associated with present or past denudation surfaces whereas the chert is so rare in the fresh unweathered rock."

(2) Weathering

(a) Evidences against weathering. Twenhofel[1]

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1 Twenhofel, W.H. Treatise on sedimentation.

says regarding the theory proposed by Ulrich, "What Ulrich was really observing was the greater accumulation of residual chert on a gentle slope than on a steep slope. As Ulrich's deduction has been cited so often by advocates of this view, it will be well to evaluate it. If a horizontal limestone containing 15 per cent of chert underwent chemical denudation, it is evident that all the chert in the beds would be concentrated at the surface as the insoluble material of the limestone. This would be the maximum quantity of chert. Increasing slightly the slope of the eroded surface would increase the carrying power of the run-off, so that at first the smaller pieces of residual chert would be removed, as the slope was increased further, more and more fragments would be carried away until finally at a vertical cliff all the chert loosened by weathering (largely mechanical) would accumulate at its base as talus or be carried away by a stream. The solid floors of chert in some valleys in the Ozark area of Missouri and in the southern Appalachian area are evidence of the activity of the streams in mechanically removing the chert. Thus to ascribe the chert on the gentler slopes to the longer and slower process of chemical weathering is not a safe assumption as the chert could have been (and probably was) originally present in the limestone."

This objection apparently accounts for everything except the fact that in the occurrences as studied by Woodward, "The cherts are prevailingly abundant upon the weathered exposures and in the residual soils of certain formations but are conspicuously absent in fresh bed-rock of these same formations."

Twenhofel says further, "Studies of hundreds of thousands of well logs prove that chert and flint are as widely distributed underground as are the formations in which they occur. Denial of this is made by some who explain chert as a product of weathering but the evidence is so overwhelming as to be incontrovertible."

Even this does not alter the fact that chert does not occur in the unweathered portions of the limestone in this particular occurrence as studied by Woodward.

Apparently closer observation of the field occurrences are necessary before this question can be definitely settled, for if the occurrences have been correctly observed by Woodward, Twenhofel's objections are automatically over-ruled.

Fragmental brown cherts are scattered profusely over the surface in some sections of the area, especially in the northern part on Point 28, S 3, T 19 S, R 25 E. However, since small lenses of chert are found outcropping at various places and no occurrences where the cherty layer on top grades into unsilicified limestone below are noted, the conclusion is that the Suplee cherts are not the result of surfacial weathering.

e. Theories of syngenetic origin

In order to be strictly syngenetic in origin the chert must have been formed contemporaneously with the limestone. Exponents of the syngenetic origin are divided in opinion as to the source of the silica. One group holds that the silica is of organic origin, the other that the silica is of inorganic origin.

(1) Organic origin of silica

According to the organic theory part of the shells or skeletal remains of siliceous organisms is dissolved by the sea water and reprecipitated. The silica then cements the undissolved portions of the organisms and cherts containing remains of radiolaria, diatoms and sponge spicules result from the consolidation of the mass.

(a) Evidence for the organic origin of the silica. The presence of the remains of radiolaria, diatoms, sponges, and other siliceous organisms within the chert constitutes the main evidence for this theory. The high silica content of certain waters was supposed to result from the numerous siliceous organisms present. Discussing the origin of cherts in the Boone limestone of Arkansas and Missouri Purdue and Miser say[1]: "The bedded cherts were for the most part siliceous deposits and owe their present nature only in small part to segregation.

"The silica could have been lain down contemporaneously with the limestone forming material (1) as fine grained detretal quartz, (2) as a deposit derived from organic remains, or (3) as a deposit by chemical precipitation in a colloidal form. The purity of the limestone leads the authors to attribute the silica to one or both of the two sources last indicated. Sponge spicules have been recognized in only a few places and the apparent general absence of these spicules and other siliceous tests is adverse to but does not disprove the assumption of its organic origin, for such remains would have

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1 Purdue, A.H. & Miser, H.D. U.S.G.S. Folio, No. 202., p. 10.

been largely or wholly destroyed by partial crystallization of silica and its segregation by ground water. The fact that silica of organic origin is more soluble than that of chemical origin inclines one to consider siliceous organisms the most probable source of the silica."

Diller[1] and Smith[2] describe radiolarian chert in Oregon. Smith found some recognizable genera of radiolaria but "In most cases, however, small round areas filled with cryptocrystalline silica showed where the tests had been."

(b) Objections to the theory. The organisms are considered as merely incidental in cherts since numerous occurrences are cited in which the cherts contain no evidence of siliceous organisms. The high silica content of the waters is considered to be a favorable habitat for siliceous organisms consequently they accumulate in the places where the silica is present in abundance.

"Nearly every supporter of the organic theory has considered that there is more or less subsequent alteration and rearrangement of the silica and that chert and flint may also be formed in other ways."[3]

Richard and Bryan[4] concluded that "(1) high silica content must be regarded as having a chemical rather than a biological origin.

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1 Diller, J.S. Redding Folio, U.S.G.S., No. 138, 1906. Port Orford Folio, No. 89. Roseburg, Folio, No. 49.

2 Smith, W.D. Notes on the radiolarian cherts in Oregon. Amer. Jour. Sci. Vol, XLII, Oct. 1916.

3 Twenhofel, W.H. Treatise on sedimentation. p. 540-41.

4 Richard, H.C. & Bryan, W.A. Australasian Ass'n. for the advancement of science, Vol. XVI, 1923, p. 309-315.

(2) The radiolaria are not so much the cause of the high silica content as they are the result of the highly siliceous state of the waters in which they lived."

The Suplee cherts generally show the round or ellipsoidal clear areas which are interpreted as being radiolarian remains, however, actual remains of siliceous organisms have not been noted. All traces of the organisms, however, may be obliterated by recrystallization.

Since the consensus of opinion among students of the subject is that the radiolaria are incidental, occurring associated with the cherts as a result of the highly siliceous state of the waters in which they lived, this paper will not attempt to establish the organic origin of the cherts, but will only record the fact that the evidence used by the exponents of the theory is present.

(2) Theory of inorganic origin of silica

(a) Tarr's theory of chemical precipitation.

The theory of inorganic origin of the silica as proposed by Tarr[1] is as follows: "Silica is derived from the land by chemical weathering and transported to the sea by streams as colloidal silica. Areas of low-lying lands especially peneplained areas where chemical denudation predominates over mechanical would be especially favorable for furnishing increased quantities of silica. The colloidal silica is believed to be precipitated in the sea by action of the alkali salts in the sea water after it had undergone considerable dispersion and a considerable amount of concentration. Since it is the tendency

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[1] Tarr, Amer. Jour. Sci. Vol. 44, 1917. p. 409-51.

of all colloids to aggregate into globular masses, a tendency which is very powerful in silica, it is believed that silica thus precipitated on the sea bottom would tend to assume more or less globular or elliptical forms. Under burial these forms would become compressed into elliptical or lenticular shapes by the weight of the accumulating sediments. Organisms falling into this soft colloidal mass would be perfectly preserved."

1. Evidences for the theory. The amount of silica carried to the sea annually according to Clark's averages is in excess of 22×10^7 tons. The amount of silica added to the sea is exceeded by that of only one base calcium.

"This silica is not accumulated in sea water, for analyses show mere traces. Silica using organisms account for a small percentage, but where the remainder is precipitated and how have not yet been positively determined." (Twenhofel. Treatise on sedimentation) The conditions for the most rapid removal of the soluble salts from the land are when mechanical erosion lags somewhat behind essentially complete rock decay. More silica is obtained from areas of igneous and metamorphic rocks than from areas of sedimentary rock. Leith and Mead estimate that there is 23.17 per cent of silica freed by the alteration of the average igneous rock. Under conditions of complete chemical decomposition practically all of this silica is removed as colloidal silicic acid.

Peneplanation favors chemical denudation and deposits made in those periods during which the lands were low-lying should contain chert, the amount depending upon the petrologic character of the land drained.

The colloidal silica which is brought to the ocean by the rivers is distributed by the currents. Dispersion is aided by the slow rate of concentration of the silica. Certain salts i.e., hydrogen sulphide in solution aid in dispersion by preventing the formation of a gel, Rapidity of precipitation depends upon the salinity of the water. If waters were receiving much clay or fine silt the colloidal silica would be coagulated by the sea-water and carried downward by the sinking clay and silts. When the waters were relatively free from such fine silts the currents would transport the colloidal silica to a much greater distance.

By means of a series of experiments it was shown quantitatively and qualitatively that sea-water is able to precipitate the silica added to it by rivers. The silica is probably not precipitated at once, but accumulates in the form of a colloid until it is sufficiently high concentration to be coagulated. This explains the occurrence of the silica in layers at varying intervals in the limestone.

The cause of precipitation is the coagulating effect of the saline sea-water which can be regarded as essentially an electrolyte. The colloidal silica after deposition and covering by later material would occur as nodules of elliptical outline, elongated masses and as beds.

2. Objections to the theory. (1) Arching of beds shows growth of the nodules subsequent to the deposition of the enclosing bed. It has been proved, however, that such arching occurs also over any object on the sea floor. (2) Method of precipitation inadequate, but experimental proof has shown that direct

precipitation can occur, and the rapid disappearance of silica on reaching the sea proves that it has occurred in sea-water. (3) Silicification of fossils proves that replacement does occur. The abundance of unreplaced calcareous fossils both within and without chert nodules shows, however, that this sort of replacement is unusual. Moreover the fact that calcareous fossils can be buried in the silica gel without being replaced is a strong argument against replacement. (4) No chert in the initial stage of formation has ever been observed under natural conditions, but according to Mansfield[1] the present is a time of unusual continental elevation. "Probably nowhere a condition of lowlands or of a peneplain that approaches quite the condition postulated by Tarr." (5) Dean[2] says that "if the silica is precipitated by the salts of the sea these salts or at least their cations should be the principal material absorbed by the silica and hence form the principal impurities of the chert. Since sodium chloride is the salt present in largest amounts in sea-water we should expect to find a predominance of sodium and a decided predominance of calcium and magnesium carbonate."

(b) Siliceous springs. Davis concludes that there are serious objections to any hypothesis which regards all the silica of the cherts as due to radiolaria or other organisms. He regards these organisms as being merely incidental fossils which were imbedded in gelatinous silica. The addition of inorganic silica he regards as highly probable. The idea that the dilute

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1 Mansfield. Some problems of the Rocky Mt. phosphate field. Econ. Geol., Vol. 26. 1931.

2 Dean, R.S. Formation of Missouri cherts. Amer. Jour. Sci., Vol. 45. 1918. p. 411-414.

silica in river water could furnish the additional silica, he regards as an impossible explanation, although he fails to give adequate reasons for his conclusion. He suggests siliceous springs as a possible source of the silica. The springs were assumed to be connected with intrusions. There is no evidence as yet which would support the theory that siliceous springs contributed the silica for the formation of the Suplee cherts.

The only intrusive bodies are those of Post Paleozoic age and the presence of cherts in the basal Triassic points to the conclusion that the cherts were formed before the area was intruded.

f. Theory of pene-contemporaneous origin

Van Tuyl thinks that replacement proceeded on the bed of the sea possibly contemporaneous with the deposition of the limestone, the silica of inorganic origin having been deposited in a colloidal condition on the bed of the sea while the limestone was being formed.

Twenhofel[1] says of this theory, "according to this theory the silica is first precipitated and deposited (supporters of the theory do not state by what agency precipitation of the silica is brought about) on the sea floor along with the materials of the enclosing rock just as is advocated under the direct-chemical precipitate theory, after the deposition of the silica and calcium carbonate, However, the silica is supposed to go into solution and then be re-precipitated and redeposited displacing or replacing surrounding

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1 Twenhofel, W.H. Treatise on sedimentation.

sediments as this takes place, and eventually to become chert and flint nodules. Why this additional stage or process of solution following initial chemical precipitation should take place, it would be hard to say, especially as the dissolved silica is then supposed to be again precipitated and deposited in like manner as before. This theory can in no way account for great bedded deposits like the Lake Superior cherts and even its advocates use it only in explaining the origin of nodules."

g. Summary of evidence and conclusions

This paper will not attempt to evaluate the evidence for or against the various theories of chert origin, but has only made an attempt to fit the criteria to the field occurrences of the Suplee cherts in so far as observed.

The distribution of the cherts in well defined beds and the rhythmic alternation of the beds of chert and limestone seems to favor the theory of chemical precipitation as stated by Tarr. It is doubtful if emanations from siliceous springs or accumulations of radiolaria would produce the rhythmic interbedding noted.

The massive beds of chert near the top of the section is consistent with Tarr's theory. Also, since he postulates that silica would be brought to the seas and deposited in greater abundance during times of peneplanation when the work of streams consisted largely of chemical rather than of mechanical erosion, his theory is applicable. Twenhofel[1] states, "that the statement is sometimes made that cherty horizons are associated with unconformities. If a

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[1] Twenhofel, W.H. Treatise on sedimentation.

marked connection existed between peneplanation (with resultant greater chemical denudation in the later stages) and an abundance of limestone and chert, then chert should be more abundant in the upper part of a limestone bed."

Cherts are found in the mechanical sediments of the Triassic and Jurassic formations. These cherts are evidently derived from the Paleozoic since they are often associated with limestone boulders containing Paleozoic fossils. This occurrence places the time of formation of the cherts as pre-Triassic.

The situation seems to be the same as that cited by Tarr, and the conclusions are obviously the same, that the time of formation of the chert is thereby limited to the period between upper Mississippian and Triassic. This cannot be considered as conclusive evidence of either epigenetic or syngenetic origin, but to be considered epigenetic special conditions must be postulated to explain why the chert was formed only during this period between late Paleozoic and Triassic.

The presence of replaced fossils in the cherts is cited as being evidence of replacement, but Tarr refutes this argument by stating that organisms may fall incidently into the soft mass of silica. The fact that the interior of some fossils is still calcareous, the silica forming a crust around the outside, may be considered as corroborative evidence to this statement.

The presence of irregular patches of limestone within the body of the chert is also cited as evidence of secondary origin of the chert, since they may represent unreplaced remnants, but according to Twenhofel this occurrence is as easily explained as being due to particles of limestone being deposited in the chert during its accumulation.

In thin-sections of limestone cherts are seen to occur as isolated fragments of subangular or rounded outline; these fragments consist of quartz mosaics with occasional chalcedony. There is no apparent relationship between the fragments and the structural or textural features of the limestones. Some of the limestones in which these cherts occur are entirely crystalline yet at no place had the chert assumed the form of the replaced calcite. Either replacement had taken place before the crystallization of the limestone or the cherts were there because of some other reason.

If the cherts were there as a result of replacement before the crystallization of the limestone the time of formation is again confined to a definite period during which period special agents were operative.

A particle of chert has been noted within the shell of a foraminifera which occurs as a fossil in the limestone. This chert fragment is entirely surrounded by calcite and is not connected with any apparent structural lines in the limestone. Such an occurrence may be explained by silica entering the foram shell while the silica was still in the colloidal state, since to attribute the chert to replacement would neccessitate explaining why the chert occurred in such a minute quantity within the shell when there were no other evidences of cherts near the shell.

In the vicinity of White Butte S 16, T 18 S, R 25 E and in the

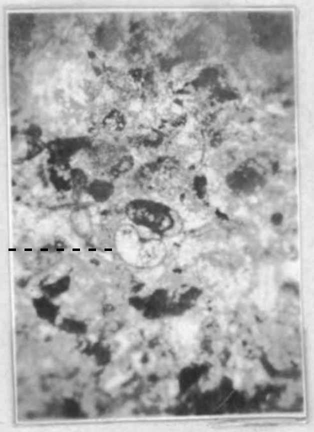
Photomicrographs of chert in thin sections.

Nicols crossed


chert

Chert with clear area
showing dark cross

Clear spots in chert
composed of quartz
mosaic



Limestone showing cross-section of foraminifera enclosing particle of chert central part of S 8, T 19 S, R 25 E mechanical sediments occur which have a siliceous cement. Why certain sandstones have silica as a cementing material while others do not is a question which may be explained by the fact that during times of flood the rivers were carrying mechanical sediments as well as chemical sediments. Twenhofel states that when rivers were carrying mechanical sediments the precipitated silica would be disseminated throughout the clastics.

The conclusion to be drawn from the facts given above are that Tarr's theory of direct chemical precipitation seems to best fit most of the occurrences of the Suplee cherts. However, replacement also seems to have played a minor part in the formation of the cherts though only in a few localities. Evidence for the theory that the silica of the cherts may be of organic origin is also present.

Probably no one agent can be made responsible for the formation of all cherts, several agencies are probably operative and different agents may operate in different localities. In the Paleozoic cherts evidence is at hand which shows three agents to have been active; but that is no reason to assume that all cherts must be formed by these same methods. The field relationships, and occurrences must be the governing factors in any attempt to solve the problem of chert origin.

F. Igneous

The igneous rock is very likely post-Paleozoic in age, but since it is apparently an intrusion into the Paleozoic formations it may well be discussed together with the Paleozoic.

1. Areal extent.

Part of this intrusion is seen outcropping in the vicinity of Mills upper Ranch where it occurs as an elongated outcrop corresponding in strike to the Paleozoic strata and as an outcrop almost at right angles to strike of the Paleozoic. Mills Butte, S 25, T 18 S, R 25 E, and the prominent ridge to the west, S 26, T 18 S, R 25 E, as well as a few isolated hills are composed of this material and are surrounded by shales and shaly sandstones, the strike of which is almost at right angles to the strike of the Paleozoic and the age of which has been placed as Jura-Trias. The other part of the intrusion, the outcropping of which corresponds in strike to that of the Paleozoic is represented topographically as an elongated ridge which extends from the base of Iron Mountain, SE $\frac{1}{4}$ S 23, T 18 S, R 25 E to a short distance north of the Flatiron locality, S 5, T 19 S, R 25 E, where it dies out. The rock weathers to a reddish color and the hills composed of this material have a decided reddish cast, however, this is not a good criteria for determining hills composed of the igneous material since some of the weathered Mesozoic sandstones present a similar appearance. This red color is probably due to an iron oxide formed during the weathering of the rock.

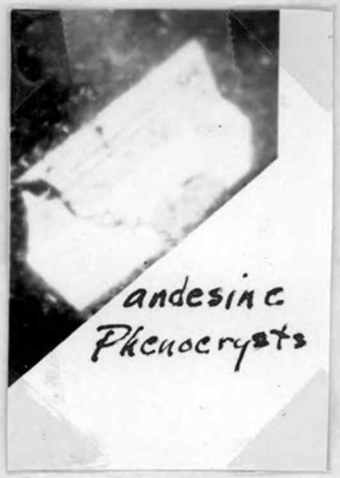
The intrusion apparently was made along the bedding planes of both Mesozoic and Paleozoic formations and that part which is associated with the Paleozoic is very near the contact between the two Periods.

2. Megascopic description

In the hand specimen this rock is porphyritic having a dark colored, fine-grained groundmass in which are contained phenocrysts of plagioclase which averages about .5cm. in cross section. On close examination the rock has a greenish cast apparently due to the presence of chlorite. The phenocrysts are fairly abundantly distributed in the groundmass; a cross section two cm. square containing from five to seven phenocrysts.

3. Microscopic description

Under the microscope the above rock exhibits the following characteristics:



Texture

Granularity. Phenocrysts phanerocrystalline. G.M. microcrystalline.

Crystallinity: Holocrystalline

Fabric: Porphyritic, Dopatic $\frac{g.m.}{Ph}$ $\frac{7}{1}$ $\frac{5}{3}$

Mega phenocrysts

Mineral composition

Primary.

Phenocrysts		Groundmass	
Andesine	90%	Augite	15%
Augite	10%	Magnetite	10%
		Medium oligoclase	65%
		Oligoclase andesine	8%

Secondary - 2%

Chlorite alteration product of augite

Raolin alteration product of feldspar

limonite alteration product of magnetite

Order of crystallization

Augite and andesine phenocrysts

Magnetite, augite, oligoclase andesine, oligoclase.

Remarks

Phenocrysts of augite and andesine Euhedral. Augite phenocrysts shows evidence of resolution around the margins. Chlorite also formed around margins.

Name: A 5-7 II p_x^{15} (Hodge) Gauteite (Iddings)

This rock has been called an andesite porphyry when referred to on the accompaning map and in the thesis.

In the northern part of the area about a mile south of Suplee another intrusion occurs. The general outline of the outcrop is a gentle curve with the convex side of the north. This rock varies somewhat in appearance from the above described, although the actual mineral content is essentially the same.

2. Megascopic description

Porphyritic, groundmass is dark in color and has a greenish cast. The phenocrysts are somewhat larger than those of the previously dexcribed rock being about .7 cm. in cross section and they are also less abundant, a cross-section two cm. on a side containing from three to five phenocrysts.

3. Microscopic description

Texture

Crystallinity - Hypocrystalline $\frac{\text{crystals}}{\text{glass}}$ $\frac{7}{1}$ $\frac{5}{3}$

Dominantly crystalline

Granularity

Phenocrysts - Phanerocrystalline

Phenocrysts of feldspar Euhedral

Fabric

Porphyritic dopatic $\frac{\text{g.m.}}{\text{Ph}}$ $\frac{7}{1}$ $\frac{5}{3}$

Mega phenocrysts

Mineral constituents

Primary

Phenocrysts		Groundmass	
Andesine	100%	Glass	10%
		Magnetite	50%
		Augite	20%
		Oligoclase	5%
		Olig. ande.	60%

Secondary

Chlorite

Limonite

Kaolin

Order of crystallization

Andesine phenocrysts. Magnetite augite, oligoclase, oligoclase andesine, glass

Name

A 5-7 II $p_x 20$

Although these two crops vary somewhat in their general characteristics the similarity of their mineralogical content make it appear quite probable that both crops are associated with the same intrusive mass.

V ECONOMIC GEOLOGY

A. Limestone

The vast amount of limestone in this area is potentially of economic importance since some of it can be used in the manufacture of Portland cement and as a fertilizer.

The cherts associated with the limestone would render some of it unfit for use but in various parts of the area limestones are found which are exxentially pure calcium carbonate. These could be scooped out by means of a steam shovel, thus the cost of obtaining the limestone would be minimized.

Under present conditions of transportation the expense of removing the limestone to the markets would be prohibitive. However, it is to be noted that central Oregon has these resources and future development of the region resulting in the improvement of transportation facilities will no doubt see these deposits developed.

B. Petroleum

Unfortunately anticlinal structures in sedimentary rocks have come to carry a connotation of petroleum, but it is a well known geological fact that anticlinal structure along is not the only factor to be considered in searching for petroleum deposits.

The structure of the Suplee Paleozoic is anticlinal, but the top of the anticline has been worn away and the individual beds truncated. The strata has been subjected to enormous stresses which have resulted in the formation of an intricate network of joints or fractures in the rock which very likely penetrate to great depths. Under such conditions any petroleum which may have been compounded by the anticlinal structure would have ample opportunity to escape.

If the process of escaping was operating at the present time, oil seeps or asphalt pits should bear witness to this fact. Therefore, the conclusion is that operations for the production of petroleum in this area must be of a purely speculative nature, since geologic evidence points to two conditions. Either no petroleum was ever present in the strata or it has long since leaked out through fissures and the evidence of this seepage has even been wiped out by the geologic agent of erosion.

Diagram illustrating the following stages in the geologic history of the Paleozoic series:

a. Deposition

b. Deposition and peneplanation

c. Uplift with Mesozoic sediments deposited on margins.

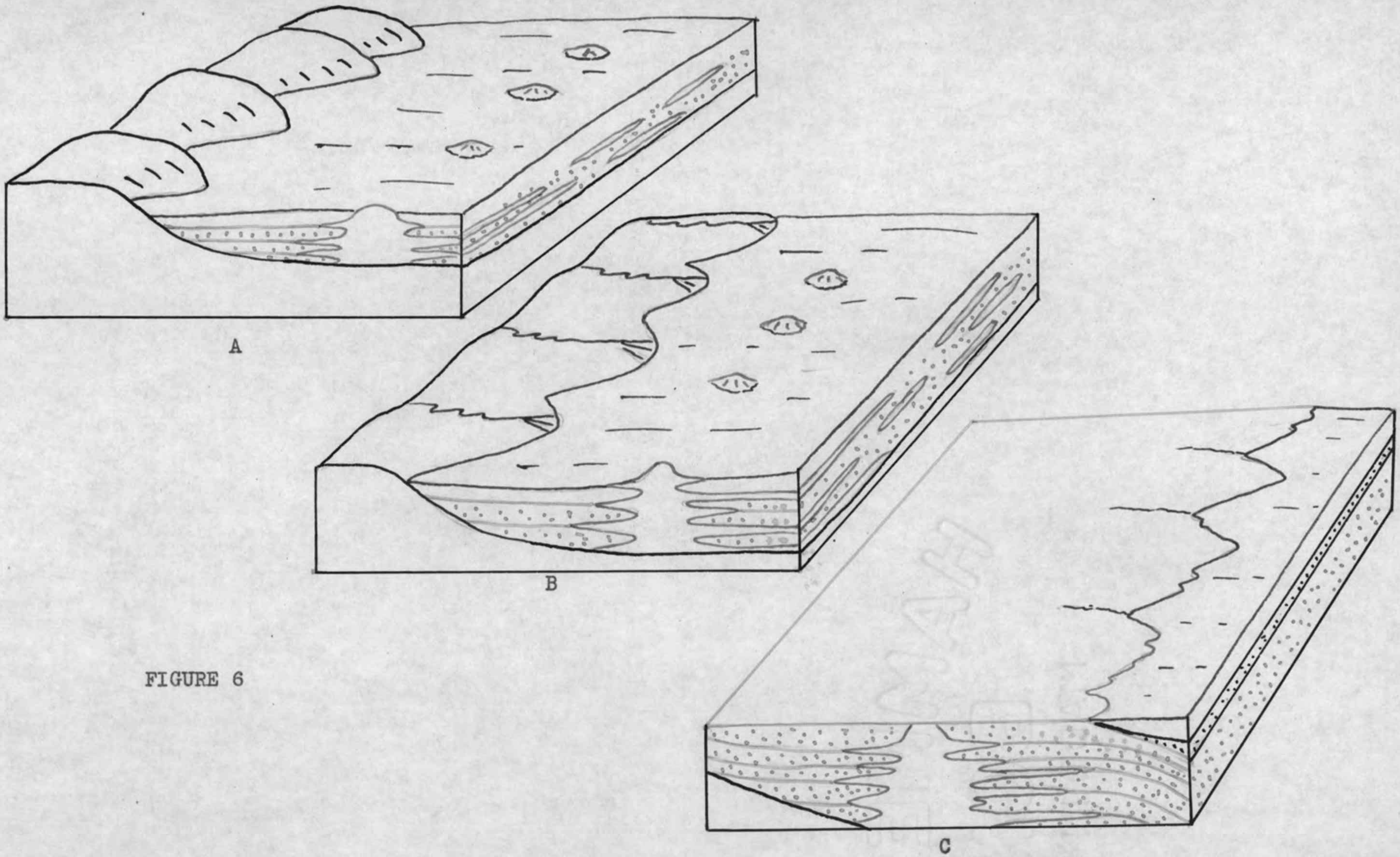


FIGURE 6

VI GEOLOGIC HISTORY

Preliminary faunal studies in Oregon by Packard[1] and Gonzales[2] indicate the presence of a fauna similar to that of the Baird formation of Northern California and to others extending northward through southeastern Alaska. The distribution of this fauna indicates the presence of a seaway extending south from southeastern Alaska through central Oregon and northern California as an arm of a sea which occupied what is now western Europe and northern Asia.

The lands bordering this trough or seaway must have been high with prominent headlands. Much talus accumulated at the base of these headlands and consequently the boulder facies along the shore were numerous. Fig. 6 A.

Rivers carrying large amounts of sediments dumped their loads into the sea thus building up accumulations on the margins of the lands. Part of this material was distributed by the shore currents but large quantities of it remained in place. Most of the material was apparently derived from sources near the sea since it shows very little evidence of water sorting or transportation. This material was at first dropped into relatively deep water below the action of the waves and therefore remained angular. The condition of a rising land mass and a sinking sea bottom caused great accumulations of coarse angular mechanical sediments. A period of stability was reached, however, and as the mature profile was approached and

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1 Packard. op. cit.
2 Gonzales. op. cit.

the angle of slope along the margins became lower, the waves swept over the beaches as a sheet flood and instead of rolling boulders merely pushed them slightly forward as the waves swept in, and backward as they receded. This resulted in flattening of the larger boulders, which are in such evidence in the conglomerates and especially in those conglomerates containing the larger sized cobbles.

The sediments indicate that at the time they were being deposited reefs composed of brachiopods, corals or crinoids, together with an abundance of foraminifera, bryozoans and possibly calcareous algae were growing off shore. The detrital material torn from the reefs by wave erosion, together with calcium carbonate precipitated as a result of local concentration near the reefs, were deposited with the mechanical sediments and formed interdigitating deposits of limestone and mechanical sediment. Fig. 6 B.

Peneplanation of the land mass followed, Fig. 6 B, accompanied by the deposition of a large body of chert. The chert representing the silica which had been derived from the land by chemical denudation and deposited in the sea by the chemical action of the salts of the sea water. The cherts represent the last deposition before the end of the period and are thus associated with an unconformity.

Following this, these sediments were uplifted, though not greatly deformed, Fig. 6 C, and the area was apparently the source of material for Mesozoic strata, deposited in seas which at one time or another during the Mesozoic era lapped on all sides of the Paleozoic land mass.

Diagram illustrating the following stages in the geologic history of the Paleozoic series:

d. Folding of sediments
e. Folding and faulting
f. Erosion

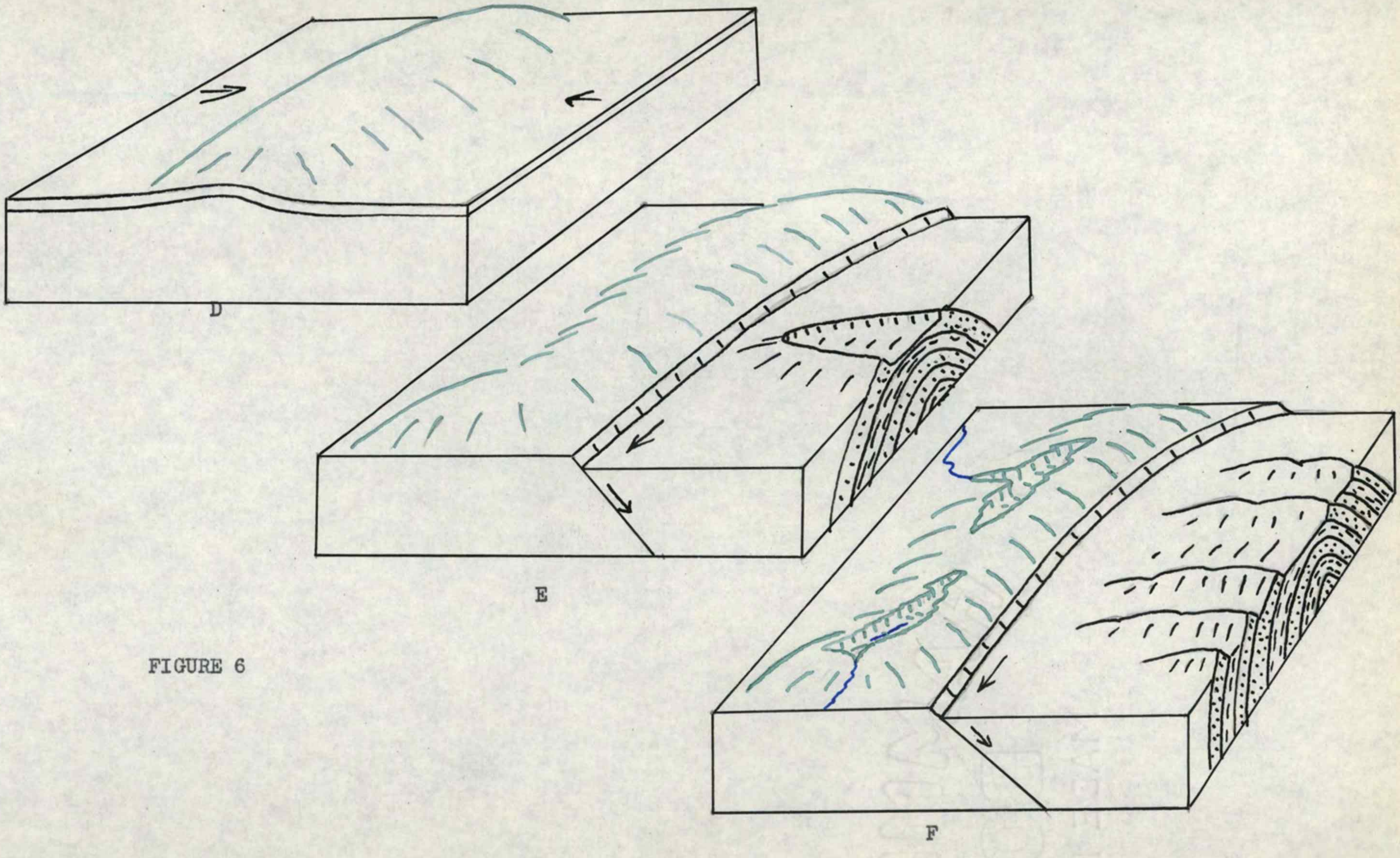


FIGURE 6

Mountain making then predominated throughout the whole region, and the Paleozoic and Mesozoic sediments were thrown into steeply dipping folds, the strike of which was approximately north and south, Fig. 6 D. This was followed by deformational stresses operating from the north and south which contorted the anticlines formed by the previous deformation and apparently accompanied by faulting with both horizontal and vertical displacement which threw the Jurassic entirely out of position so that the strike of the Jurassic strata was cut off by Paleozoic strata striking almost at right angles to it. Fig. 6 E.

The consequent streams down the slopes became controlled by the jointing which resulted from the deformational stresses and breached the Paleozoic anticline in the south and doubtless in other places also. Fig. 6 F.

The Paleozoic was probably generally of higher elevation than the surrounding country and an escarpment resulting from the faulting separated it from the Mesozoic on the east.

Over this physical set-up the late Tertiary lavas were poured, Fig. 6 G. They covered the Mesozoic and perhaps abutted against the Paleozoic escarpment, and flowed up the drainage channels on all sides of the Paleozoic land mass, damming the streams and producing temporary base-levels through which the streams gradually cut. The event was registered by the filling of the stream valleys and the meandering of the streams over these filled valleys while it cut through the surrounding lavas.

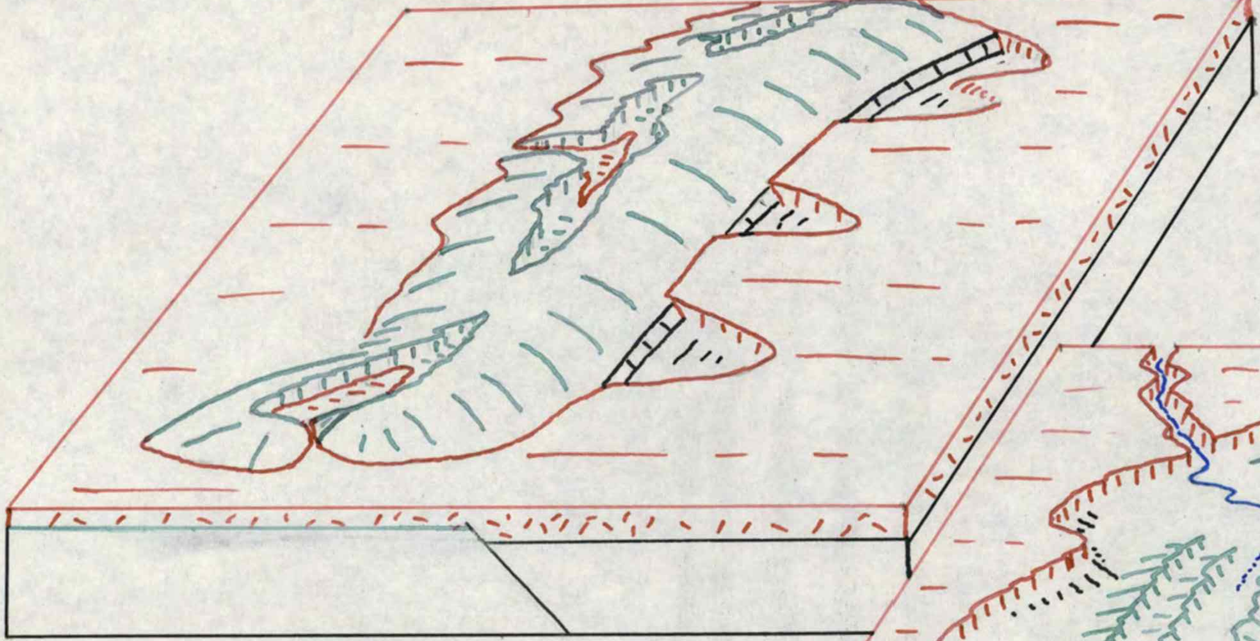
Post-Tertiary deformation produced a divide in an east-west direction across the area from Wade Butte to Iron Mountain. Intermittant streams developed on the slopes of this divide and flowed into the east-west streams flowing across the area.

The topographic features noticeable today are largely the result of the action of these streams which was in turn guided by the character of the sediments deposited by and in the ancient seas, the tectonic forces acting upon these sediments and the volcanic disturbances which changed the character of all the regions over which they were active.

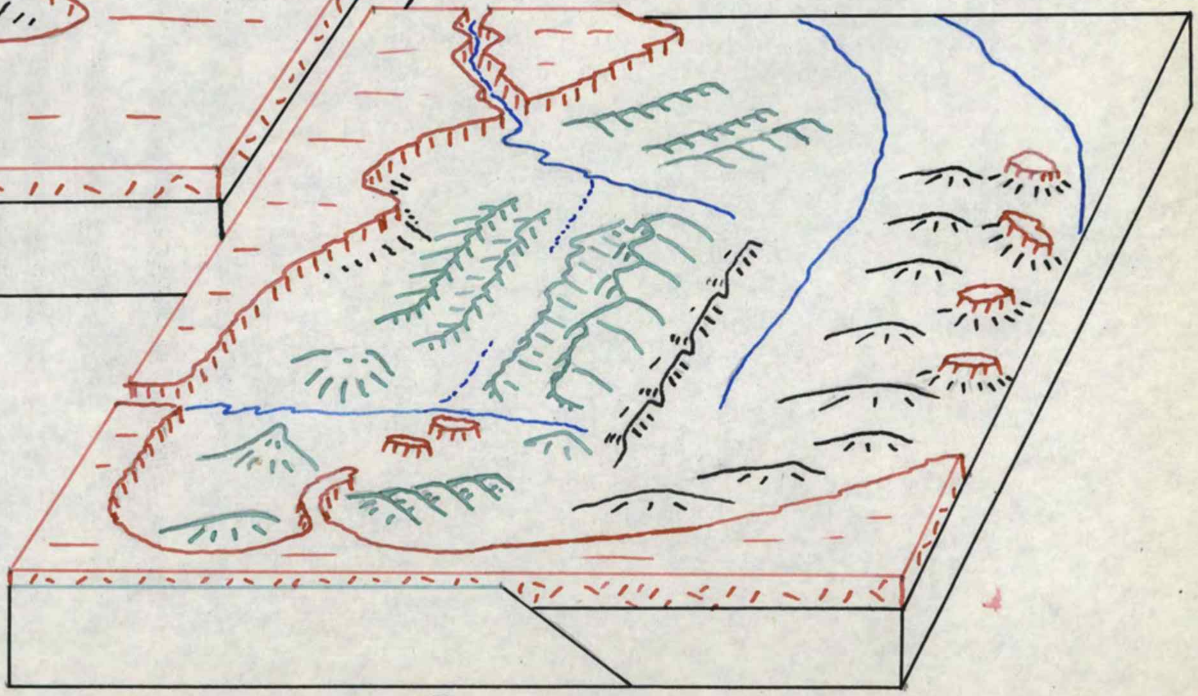
Diagram illustrating the following stages in the geologic history of the Paleozoic series:

g. Flooding by Tertiary lavas

h. Subsequent erosion producing present topographic features



G



H

FIGURE 6

VII SUMMARY

The Paleozoic series occurs as a window in the Tertiary lavas, the lavas forming on the north, west and south sides of a semi-circular escarpment about the mature Paleozoic hills. On the eastern side the Mesozoic abutts against the Paleozoic, the contact being marked by a well defined escarpment composed of Paleozoic cherts.

The area is subdivided into three sub-sections, the divisions being made according to the type of topography. The topography is found to be directly dependent upon and resulting from the structure and lithology of each particular sub-section.

The drainage system consists of four master streams which cut directly across the strike of the strata, and subsequent streams eroding at right angles to the master streams in the less resistant strata forming a trellis drainage pattern.

The direction of the master streams is the result of system of joints and their relation to the drainage slope. The structure of the series is anticlinal, the axis of which shows evidence of deformation due to longitudinal thrusting from the north and south, the axes of warping are so spaced that they divide the anticline into three approximately equal sectors, so that the crest of the anticline forms a symmetrical reverse curve. The Paleozoic series is apparently structurally conformable with the overlying Mesozoic formations but a hiatus must occur between the two.

The jointing is very complex; however, the more prominent joints appear to have a direct relationship to the deformation of the area.

Faulting is not extensive, and conclusive evidence for anything but very minor movements has yet to be found, although there is some evidence that major movements have taken place.

The area is composed of limestones, mechanical sediments, and cherts with post-Paleozoic intrusives. The limestones are thought to be due to reefs and to detrital material derived from the reefs being interbedded with the mechanical sediments derived from the land.

The sandstones and grits are composed mainly of cherts, but due to their occurrence as interbeds with the limestone and the lack of Paleozoic limestone fragments incorporated within them, points to the conclusion that they must be considered as part of the Paleozoic series. They are composed mostly of angular or sub-angular fragments and apparently were deposited as deltas on the margins of the pre-Mississippian land mass. The conglomerates usually c ontain flattened boulders which are thought to have become flattened by a backward and forward movement on the beach.

The cherts are vari-colored and the occurrence and field relationships indicate that a small percentage were formed by replacement, some may have been due to the accumulation of organisms, while the majority apparently are the result of chemical precipitation.

Igneous bodies of post-Paleozoic age have been intruded as dikes into the Paleozoic sediments in various places on the eastern flank usually near the Paleozoic-Mesozoic contact.

These rocks have been classified as andesite porphyries.

At the present time the region is of very little importance economically since petroleum possibilities are very meager and the limestones too far from market. However, improvements in the transportation facilities may cause the limestones to become of economic importance.

The sediments were deposited in a seaway which extended from northern California through Oregon to southeastern Alaska as an arm of a sea which covered what is now western Europe and northern Asia. The condition of a rising land mass and a sinking sea bottom caused great accumulations of coarse mechanical sediments. Reefs growing off shore contributed detrital material which together with the calcium carbonate precipitated by local concentration near the reefs formed beds of calcareous material which interfingered with the mechanical sediments.

As the land mass approached peneplanation silica transported to the sea by the rivers was deposited and became chert beds. The sediments were then uplifted and deformed. Tertiary lavas poured out and surrounded this uplifted mass but did not cover it entirely, thus producing a marked topographic unconformity.

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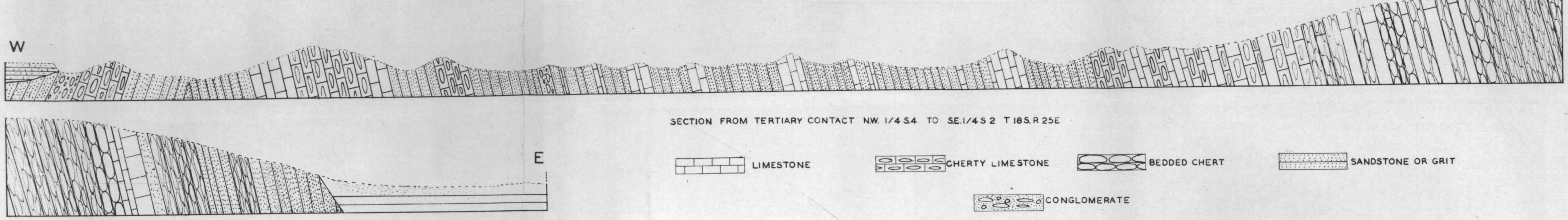
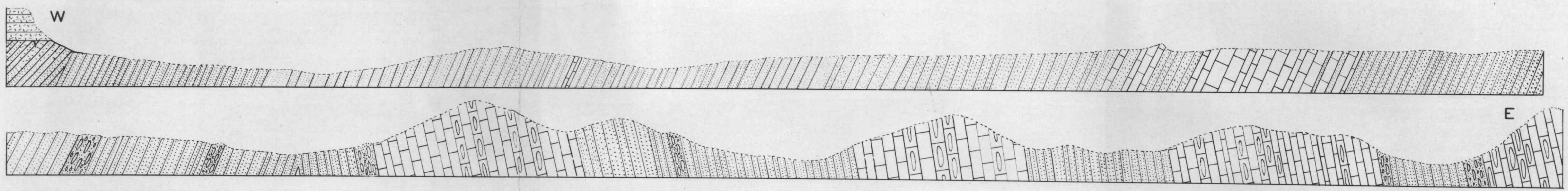
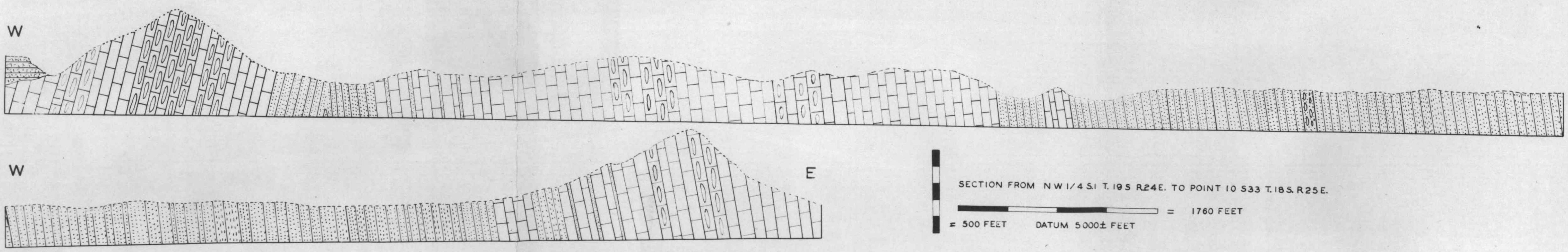


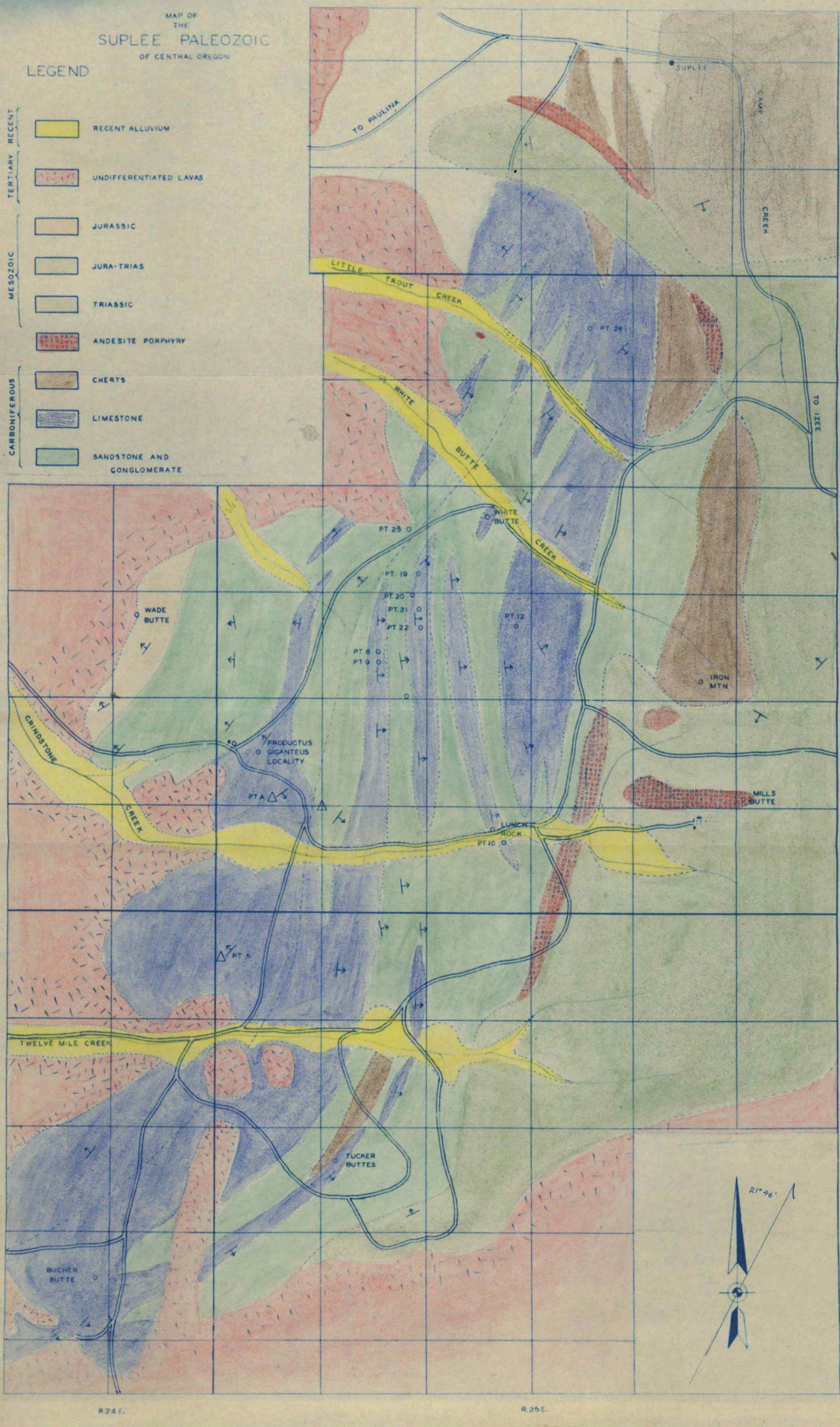
SECTION FROM TERTIARY CONTACT NW. 1/4 S.4 TO SE.1/4 S 2 T.18S. R 25E



SECTION FROM NW CORNER S 25 T.18S. R.24 E. TO LUNCH ROCK NE 1/4 S. 33 T.18S. R.25E.



SECTION FROM NW 1/4 S.1 T. 19 S R.24E. TO POINT 10 S33 T.18S. R.25E.


MAP OF
THE
SUPLEE PALEOZOIC
OF CENTRAL OREGON
LEGEND
RECENT
TERTIARY
RECENT ALLUVIUM
UNDIFFERENTIATED LAVAS
MESOZOIC
JURASSIC
JURA-TRIAS
TRIASSIC
ANDESITE PORPHYRY
CARBONIFEROUS
CHERTS
LIMESTONE
SANDSTONE AND CONGLOMERATE
TO PAULINA
SUPLEE
CAMP CREEK
LITTLE TROUT CREEK
WHITE BUTTE CREEK
TO IZEE
PT 28
PT 25
WHITE BUTTE
PT 19
PT 20
PT 21
PT 22
PT 12
PT 8
PT 9
WADE BUTTE
IRON MTN
GRINDSTONE CREEK
PRODUCTUS GIGANTEUS LOCALITY
PT A
MILLS BUTTE
LUNCH ROCK
PT 10
PT 5
TWELVE MILE CREEK
TUCKER BUTTES
BUCHER BUTTE
21° 46'
T. 17 S.
T. 18 S.
T. 19 S.
R. 24 E.
R. 25 E.