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THE CHIWAUKUM GRABEN, A MAJOR STRUCTURE OF CENTRAL WASHINGTON

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ABSTRACT. Chiwaukum graben is one of the major structural features of central Washington. It is on the east slope of the Cascade Mountains and northwest of the big bend in the Columbia River where the latter is confluent with the Wenatchee River. The graben (early Tertiary), which bears N 30° W, transects the structures bearing N 60° to 80° W displayed by the foliation of the crystalline schists of the basement complex. Both of these earlier structures are superposed on the broad, north-south-trending warp of the late Tertiary Cascade Uplift.

The mountains bordering the graben are not anticlinal mountains as generally considered, but are fault-block mountains, and the folds displayed by the strata of the Swauk formation within the graben are genetically related to the faulting and shearing of the basement complex which produced the graben.

INTRODUCTION

Location.—The Chiwaukum graben is near the geographical center of the State of Washington. It lies between the Entiat Mountains on the east and the main body of the Cascade Mountains on the west (fig. 1).

Accessibility.—Much of the area is readily accessible by highways and secondary roads from Wenatchee, Cashmere and Leavenworth, the three major cities in the area under consideration.

Purpose and scope of paper.—The purpose of this paper is to call attention to one of the major structures, the Chiwaukum graben, in central Washington. With this purpose in mind, emphasis is placed on structure. The petrology and petrography of the Basement Complex and Swauk formation will be covered in future papers.

Field work.—Field work was undertaken by the author during the summers of 1947, 1948, and 1949, and by students of the University of Washington and Washington State College Geology Field Course under the direction of the author and Dr. John C. Mickelson during the summer of 1951. The area mapped and its relationship to previously mapped areas are illustrated in figure 1.

Methods of investigation.—Mapping was done on topographic maps and by plane table and telescopic alidade. Four plane-table traverses (scale 1 inch = 1000 feet) were made across the graben, and one across the Entiat Mountains along the west side of the Columbia River. The areas between the plane-table traverses were mapped on topographic base maps (scale 1 inch = 2 miles).

Acknowledgments.—The author gratefully acknowledges his indebtedness to those workers[1] previously engaged in geologic studies in central Washington. Their work is acknowledged throughout the text, and the areas previously mapped by them are shown in figure 1. In particular, the author wishes to express his acknowledgment of the contributions made by the students[2] of the University of Washington and Washington State College Field Course of 1951, and Mr. Richard Rongey, field assistant to the author during the summer of 1948.

The author is greatly indebted to Dr. Howard A. Coombs for suggesting the area for study and to Doctors Howard A. Coombs and Peter Misch for critically reading the manuscript.

GENERAL STATEMENT

Introduction.—The Chiwaukum graben is one of the major structural features of central Washington, with a known length of 40 miles, a maximum width of 13 miles, and a vertical displacement exceeding 16,000 and 10,000 feet along its eastern and western margins respectively.

Basement complex.—The graben is bordered on the west and northeast by rocks of the basement complex. The rocks along the northeastern border include mica-quartz schist, amphibolite, marble, mica gneiss, peridotite which has been largely altered to a talc-carbonate rock, pegmatite, quartz veins, and the Chelan "granodiorite" which consists dominantly of quartz diorite gneiss and subordinate quantities of granodiorite gneiss and diorite. The rocks along the western border include mica-quartz schist which grades into staurolite-biotite-quartz schist and kyanite-biotite-quartz schist, amphibolite, mica gneiss, peridotite

[1] Special acknowledgment is due George Otis Smith (1904), A. C. Waters (1932), Walter M. Chappell (1936), and Ben M. Page (1939).

[2] The roster of students is as follows. Olin M. Hart, Paul J. Gribas, Melvin W. Eversaul, Edwin H. East, E. James Jacobs, Warren S. Drugg, Gordon J. Thomas, Oscar J. Ferrians, Jr., Robert J. Jensen, Donald F. Kellum, Howard A. Pelton, Robert W. Hickman, Ardian C. Boyd, Howard G. Lister, M. E. Morrison, R. O. Smith, J. D. Stephens, J. L. Gaultieri, K. U. Russell, O. L. Hetland, and H. C. Kuppler.

which has been largely altered to serpentine, pegmatite, quartz veins, and the Mount Stuart "granodiorite" which is dominantly composed of quartz diorite in the area under consideration.

Swauk formation.—The graben is floored with approximately 13,000 feet of folded and faulted, intercalated sheets and lenses of arkose, shale, and conglomerate (floodplain and stream channel deposits) of Paleocene or/and Upper Cretaceous age—the Swauk formation.

Arkose is the most common lithologic type, constituting over 75 percent of the section. It occurs in massive or cross-bedded sheets or lenses ranging from less than one to over 100 feet in thickness. The arkose is a pale gray, usually well-graded, fine-grained to conglomeratic, biotite-bearing arenite with angular grains of plagioclase (An_{22} to An_{35}) and quartz in nearly equal quantities, with minor quantities of micropegmatite, epidote, sphene, chlorite, microline, microperthite, orthoclase, muscovite, apatite, garnet, magnetite, rutile, green hornblende, and rock fragments. The grains are cemented, in part, with quartz; interstitial argillaceous material is a very minor constituent.

Shale is next in abundance, but this is inferred from a few natural exposures and artificial cuts along roads and railroads. It occurs in beds or lenses which rarely exceed a few feet in thickness. The shale is a brown to dark gray, moderately laminated, arenaceous siltstone with a mineral assemblage that is related to the arkose. Moderately to well-preserved fossil leaves have been found in some of the shales.

Conglomerate is the least common lithologic type and is largely confined to the lower portion of the section. The conglomerates at the base of the section are usually coarse and poorly graded and reflect the composition of the underlying rocks of the basement complex. Most conglomerate beds higher in the section are lenticular masses of moderately sorted, fine- to medium-gravel composed dominantly of rock types not present in the rocks of the basement complex.

STRUCTURE

Introduction.—The Chiwaukum graben is defined by two major faults, the Entiat fault on the northeast and the Leavenworth fault on the west. Major and minor structures also occur within the graben, the most important being the Eagle Creek anticline and associated Eagle Creek fault.

The Entiat fault.—The trace of the Entiat fault, which bears N 30°W, has been mapped[3] from the big bend in the Columbia River at the city of Wenatchee northwestward along the base of the scarp of the Entiat Mountains to Basalt Peak, a distance of 40 miles. The full extent of the fault trace has not been determined.

The most conspicuous and prominent feature of the Entiat fault is its associated scarp, which defines the Entiat Mountains on the west. It has a maximum height of approximately 3000 feet from its base to its crest and is rather featureless with only small streams, most of which are intermittent, cutting into its face. The drainage of the Entiat Mountains is dominantly eastward, the divide between the east and west drainage being at the crest of the scarp.

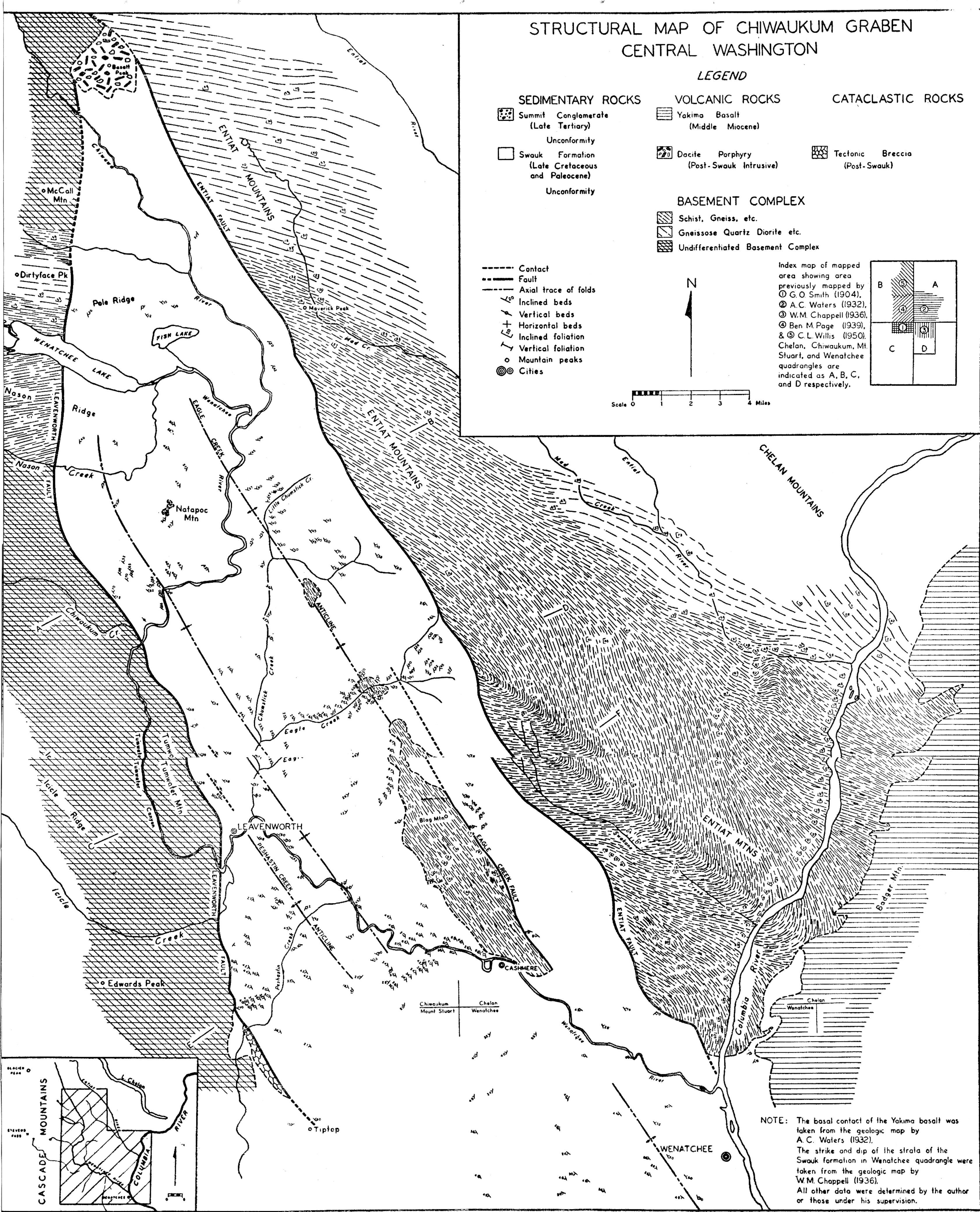
Approximately 13,000 feet of Swauk strata are truncated by the Entiat fault as illustrated by the structural map (fig. 1). The strata exposed along the Entiat fault belong to the upper part of the Swauk section and do not reflect in any way the diverse composition of the adjacent rocks of the basement complex.

The Entiat fault is a high-angle fault with a vertical displacement that must exceed 16,000 feet. This value was determined from the thickness of the Swauk strata (approximately 13,000 feet) west of the fault and the maximum height of the Entiat scarp (approximately 3000 feet).

The pre-Swauk structures displayed by the attitudes of the foliation of the crystalline schists of the basement complex are truncated by the Entiat fault as illustrated in figure 1. The attitude of the foliation of the crystalline schists conforms to a regional structure that continues on each side of the graben.

The Leavenworth fault.—The trace of the Leavenworth fault has been mapped from Basalt Peak at the apex of the graben southwestward to Chiwawa River and from Dirty Face Peak southward to Tip Top Mountain. The trace of the fault between Chiwawa Creek and Dirty Face Peak has not been mapped, and its position on the map (fig. 1) has been inferred.

[3] The trace of the fault was mapped by Waters (1932) in southwestern Chelan quadrangle, by Page (1939) in southeastern Chiwaukum quadrangle, and by Willis (1950) in northeastern Chiwaukum quadrangle.



STRUCTURAL MAP OF CHIWAUKUM GRABEN
CENTRAL WASHINGTON
LEGEND
SEDIMENTARY ROCKS
Summit Conglomerate (Late Tertiary)
Unconformity
Swauk Formation (Late Cretaceous and Paleocene)
Unconformity
VOLCANIC ROCKS
Yakima Basalt (Middle Miocene)
Dacite Porphyry (Post-Swauk Intrusive)
CATACLASTIC ROCKS
Tectonic Breccia (Post-Swauk)
BASEMENT COMPLEX
Schist, Gneiss, etc.
Gneissose Quartz Diorite etc.
Undifferentiated Basement Complex
Contact
Fault
Axial trace of folds
Inclined beds
Vertical beds
Horizontal beds
Inclined foliation
Vertical foliation
Mountain peaks
Cities
N
Scale 0 1 2 3 4 Miles
Index map of mapped area showing area previously mapped by ① G.O. Smith (1904), ② A.C. Waters (1932), ③ W.M. Chappell (1936), ④ Ben M. Page (1939), & ⑤ C.L. Willis (1950). Chelan, Chiwaukum, Mt. Stuart, and Wenatchee quadrangles are indicated as A, B, C, and D respectively.
A
B
C
D
Basalt Peak
ENTIAT MOUNTAINS
ENTIAT FAULT
Entiat River
McCall Mtn
Dirtyface Pk
Pole Ridge
Fish Lake
Wenatchee Lake
Nason Ridge
Maverick Peak
Mad Cr.
Wenatchee River
EAGLE CREEK
Nason Creek
LEAVENWORTH FAULT
Natapoc Mtn
Little Chumstick Cr.
ANTICLINE
CHELAN MOUNTAINS
Mad Creek
Entiat River
Chiwaukum Cr.
Chumstick Creek
Eagle Creek
Tumwater Mtn
Tumwater Canyon
Icicle Ridge
LEAVENWORTH
Blag Mtn
EAGLE CREEK FAULT
PESHASTIN CREEK
ENTIAT MTNS
Swakane Creek
Badger Mtn.
Icicle Creek
Peshastin Creek
ANTICLINE
CASHMERE
Edwards Peak
Chiwaukum
Mount Stuart
Chelan
Wenatchee
Columbia River
Tiptop
WENATCHEE
CASCADE MOUNTAINS
L. Chelan
RIVER
COLUMBIA
NOTE: The basal contact of the Yakima basalt was taken from the geologic map by A.C. Waters (1932).
The strike and dip of the strata of the Swauk formation in Wenatchee quadrangle were taken from the geologic map by W.M. Chappell (1936).
All other data were determined by the author or those under his supervision.

Fig. 1

From Basalt Peak to Peshastin Creek the strata of the Swauk formation are in fault contact with the rocks of the basement complex, but at Peshastin Creek where the fault trace swings southeastward into the Swauk formation the upper strata of that formation are in fault contact with conglomerates at the base of the same formation and with an inlier of brecciated Mount Stuart granodiorite.

Fault breccia and mylonite may be observed at several places along the Leavenworth fault. A nearly vertical zone of fault breccia is present on the south slope of Nason Ridge where strata of the Swauk formation abut against mica gneiss of the basement complex. Where the fault crosses Peshastin Creek and in the inlier immediately to the south, the Mount Stuart granodiorite is intensely sheared and brecciated (cataclastic breccia). Inclusions of fault breccia are present in the body of hornblende dacite porphyry at Basalt Peak where magma was injected along the fault zones of the Leavenworth and Entiat faults and out along the bedding planes of the Swauk formation to produce an asymmetrical laccolith at the apex of the graben. In the quarry west of the city of Leavenworth, well-developed mylonite is present in amphibolite.

Drag folding in the Swauk formation (fig. 2, E-F) is well illustrated on the valley wall north of Peshastin Creek where the upper portion of a thick succession of southward-dipping strata of arkose and subordinate quantities of shale and conglomerate of the Swauk formation are in fault contact with basal conglomerates of the same formation.

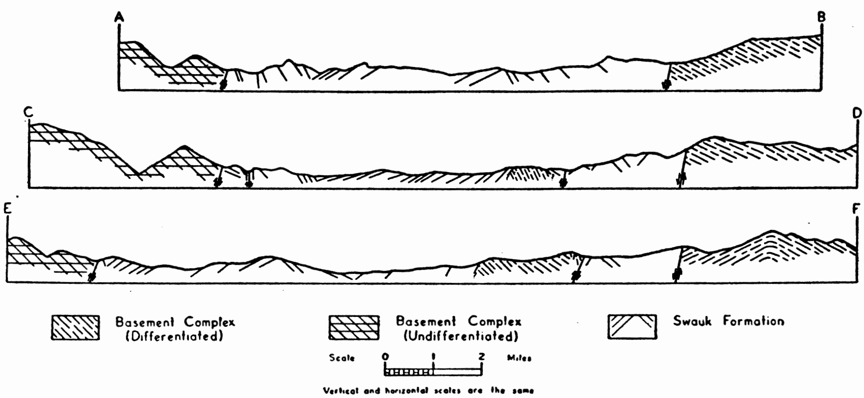


Fig. 2. Geologic cross sections of Chiwaukum graben.

The straight-line character of the trace of the Leavenworth fault where it crosses Nason Ridge, Pole Ridge, and the valley wall north of Peshastin Creek illustrates the nearly vertical attitude of the fault surface.

The vertical displacement of the Leavenworth fault cannot be definitely determined, and it undoubtedly varies in magnitude along its strike. However, the thickness (10,000 feet) of Swauk strata exposed on the western limb of the Peshastin Creek anticline (figs. 1 and 2) east of the fault suggests that the maximum vertical displacement must exceed 10,000 feet.

The Leavenworth fault, like the Entiat fault, truncates the structures of the crystalline schists of the basement complex. The relationship is illustrated in figure 1.

Eagle Creek anticline and associated fault.—The Eagle Creek anticline is the major structure within the graben. It is an asymmetrical open fold with approximately 13,000 feet of strata inclined at 30 and 40° on the west and east limbs respectively, and extends from Little Chumstick Creek, where it plunges northwestward 60°, southeastward beyond the city of Wenatchee, a distance of 34 miles.

Rocks of the basement complex are present in three inliers along the crest of the Eagle Creek anticline, the southernmost inlier being the largest with a length of 11½ miles and a maximum width of 2 miles. The crystalline schists of the inliers are moderately to intensely sheared, notably in the fault zone, the Eagle Creek fault, along the eastern margin of the southernmost inlier where strata of the Swauk formation are in fault contact with mica gneiss of the basement complex.

The Eagle Creek fault extends from the Wenatchee River northwestward along the eastern margin of the southernmost inlier and continues northwestward across Eagle Creek where a number of high-angle subsidiary faults are present in the Swauk formation. The displacement of the fault is not known.

The trace of the Eagle Creek fault bears N 30° W. It is parallel to the axial trace of the genetically related Eagle Creek anticline, is parallel to the trace of the Entiat fault, and is transverse to the structures of the rocks of the basement complex which bear N 65° W.

Mechanics of faulting and folding.—In the opinion of the author the faults and folds of the Chiwaukum graben are the results of compressional stress transmitted through the rocks of the basement complex. The rocks of the basement complex were sheared and faulted; the structures thus produced were expressed as folds and faults in the overlying strata of the Swauk formation. Evidence for this conclusion is illustrated by (1) the discordant relationship between the pre-Swauk structures of the rocks of the basement complex and the structures of the overlying strata of the Swauk formation, and by (2) the relationship between the Eagle Creek fault and its genetically related Eagle Creek anticline and associated inliers of crystalline schists.

The pre-Swauk structures displayed by the foliation of the crystalline schists of the basement complex are discordant to the structures of the Chiwaukum graben as illustrated in figure 1. These structures of the crystalline schists conform to a regional structure that continues on each side of the graben. North of the axial trace of the Swakane Creek anticline, which bears N 60° W, the foliation of the crystalline schists have a strike of approximately 65° west of north and a northeastward dip ranging between 20 and 70°; south of the axial trace of the Swakane Creek anticline, the foliation of the crystalline schists have a strike of approximately 50° west of north and a southwestward dip ranging between 10 and 50°. There is no evidence to suggest that the rocks of the basement complex were folded along with the overlying strata of the Swauk formation into folds trending N 30° W.

Faulting in the rocks of the basement complex, with associated folding and faulting in the overlying strata of the Swauk formation, is best illustrated by the relationship between the Eagle Creek fault and its genetically related Eagle Creek anticline and associated inliers of the crystalline schists. The Eagle Creek fault, at the eastern margin of the core of crystalline schists exposed in the three inliers along the crest of the Eagle Creek anticline, is parallel to the axial trace of the Eagle Creek anticline which bears N 30° W and is transverse to the pre-Swauk structures of the crystalline schists as previously described. Therefore, the core of crystalline schists of the Eagle Creek anticline is not the result of folding but rather the result of faulting in the rocks of the basement complex.

Time of faulting and folding.—The faults and folds of the Chiwaukum graben are post-Swauk (Paleocene and/or Upper Cretaceous) and pre-Teanaway (Lower to Middle Eocene) in age. In the southwestern quarter of the mapped area, diabase is present as dikes and sills in the folded strata of the Swauk formation and as dikes in the fault and shear zones along the western margin of the graben. South of the mapped area, the diabase dikes pass upward into the flows of the Teanaway basalts which rest unconformably upon the folded strata of the Swauk formation.

In late Tertiary time further deformation took place along the northwest-southeast structural trends. It is illustrated by several folds in the flows of the Yakima basalt (Middle Miocene) southeast and south of the area under consideration. An anticline, the Badger Mountain uplift, was formed southeast of the Entiat Mountains, and another, the Wenatchee Mountain Uplift, was produced southeast of Mount Stuart, the highest erosional remnant in the Cascade Mountains. These two anticlines are separated by a broad downwarp which is southeast of the graben.

Relationship between the Chiwaukum graben and the Cascade Uplift.—In late Pliocene or early Pleistocene time, the area now occupied by the Cascade Mountains was warped into a major, broad upwarp with a north-south-trending axis. This structure was superposed on the earlier northwest-southeast structural trends.

Before the Cascade Uplift, erosion had reduced the surface of the land to a broad-valley stage over a widespread area. Relics of this surface are present in the mountainous areas bordering the graben, and the Summit conglomerate on Natapoc Mountain, consisting of approximately 200 feet of horizontal beds of andesite streamlaid gravel, probably rests on this surface.

Erosion was greatly accelerated by the Cascade Uplift. Rejuvenated streams cut deep narrow canyons; sediments of the Swauk formation were flushed out of the graben; and a fault-line scarp was produced along the western border of the Entiat Mountains.

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