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Geology at the Association Meeting and Plans for 1940 Symposium on Columbia Plateau

By CHARLES D. CAMPBELL
State College of Washington
Acting Secretary, Geology-Geography Section

In this issue of "Northwest Science" are gathered some of the papers and abstracts of papers presented at the Geology-Geography Section of the December 1939 meetings of the Association. The General Secretary, the Editor, and the current officers of this Section, have agreed to continue the practice of including all articles on geology and geography, presented at the preceding meetings, in one issue of "Northwest Science". It was further agreed that the current secretary for the Section should help the Editor in the publication of this issue, to the extent of reviewing the papers and abstracts submitted for printing.

Every paper presented at last December's meetings is printed here, either in full or in author's abstract, with the exception of Professor Warren D. Smith's paper on Oregon lakes, already printed as the December 1939 issue of "Northwest Science". Included instead is a paper by H. P. Hansen, on paleoecology of a Washington peat deposit; this was not presented in the 1939 meetings.

Columbia Plateau Symposium.

During the year preceding the December 1939 meetings, representatives from the Geology-Geography Section from Washington and Idaho held several informal meetings to plan a symposium, or round-table, to be added to the regular program of papers to be presented at the forthcoming (1940) meetings. Representatives from Oregon were invited to participate. The plan of the symposium was to produce a map, with physiographic subdivisions marked, of the entire Columbia Plateau. This plan is a response of geologists in the Pacific Northwest to a growing dissatisfaction with inaccuracies about Columbia Plateau physiography, as presented in widely-circulated texts. It was thought that conclusions based on thorough discussion by geologists long familiar with the problems would serve in the future to correct some of the current impressions about Columbia Plateau physiography.

To this end, it was agreed that trial maps of the Columbia Plateau were to be drafted by representatives of the three states and sent to Otis W. Freeman, of Cheney, for use in making a coordinated map of the whole province. This work was to be done for Washington by members of the Division of Geology of the Washington Department of Conservation and Development; for Idaho by Dr. Alfred L. Anderson and the geoolgy staff of the Department of Mines and Geology, University of Idaho; and for Oregon by Dr. Warren D. Smith of the University of Oregon.

* * *

At the morning session on December 28, 1939, Dr. O. W. Freeman, being unable to be present for the symposium, his paper, concerned with suggestions about Washington's part of the problem, was read by his colleague, Mr. W. B. Merriam. Next, Dr. W. D. Smith described the proposed divisions for Oregon, dwelling at some length on an interpretation of the "horsts" of southeastern Oregon as ramp structures. Dr. A. L. Anderson, now at Cornell University, could not attend, but had sent a paper to be read at the symposium. This paper, read by Mr. Merriam also, supplied the proposed Columbia Plateau subdivisions for Idaho. Neither Mr. Freeman's paper nor Dr. Anderson's are to be published in their original form, as they were written solely as sources of debate, not as finished conclusions.

The afternoon meeting of the symposium opened with the selection of Dr. Warren D. Smith as coordinator of the discussion. Then Mr. S. L. Glover, of the Division of Geology of Washington, presented the outlines of work by the Survey staff on the Columbia Plateau subdivisions, followed by a discussion of this work, and of the three morning contributions.

Mr. V. E. Scheid and Dr. R. L. Lupher pointed out the essential continuity of the Craig Mountain-Blue Mountains piedmont, and of the Seven Devils-Wallowa Mountain tract across Snake River canyon from Idaho to Oregon; and they suggested that each of these two physiographic features receive but one name in the final map.

Dr. J. E. Upson and Dr. Lupher proposed that surface features of the Columbia Plateau be used as the basis for the major divisions, and that structures be considered only where they produce irregularities within a major division.

Mr. Stuart Twiss pointed out that at least sixteen different criteria had been offered as bases for subdivision of the Columbia Plateau.

Dr. W. A. G. Bennett suggested that areas of dissected Columbia Plateau basalt in southern Stevens County be given a special name parallel to Flint's "Okanogan Plateau" of the Omak Lake area.

Discussion proceeded along lines similar to the above until it became evident that time was far too short for a satisfactory conclusion to the symposium. Therefore, upon general agreement to continue the symposium another year, Dr. Upson was elected chairman for 1940, and it was decided that his duties were to include the following:

1. To collect material already prepared for, and discussed in, the 1939 meeting.

2. To request any new material from the three states participating.

3. In collaboration with Mr. McMacken, 1940 chairman of the Geology-Geography Section, to appoint a committee of residents of the three states to coordinate such material. This committee would be empowered to draft concrete proposals for a unified Columbia Plateau nomenclature, for discussion at the 1940 symposium.

4. To have the proposals of the above committee mimeographed or printed and distributed to participants at least one month before the December 1940 meeting.

Some Miocene Plants From North Central Idaho*

By NORMAN J. GILLETTE
University of Idaho, Moscow, Idaho

In Miocene time northern Idaho and northeastern Washington were covered with a vegetation much different from that of the present time. It had an aspect which more closely resembled our present eastern deciduous forests. One of the earlier studies on the Miocene floras of the northwest was that of F. H. Knowlton[5] in 1925. The floristic study of Knowlton accompanied a geological study of the Spokane region by Pardee and Bryan[7]. These latter authors proposed the name **Latah formation** "for a series of beds, consisting mostly of clay and shale and of fresh water origin that are found near Spokane, Wash., and that contain an abundant middle or lower Miocene flora". These rocks are often overlaid by basalt flows which are also probably Miocene in age.

Pardee and Bryan state that the rock which composed their Latah formation seems to have been derived from volcanic ash, much of which seemed to have been of an andesite type that fell in showers on the region during the period of sedimentation and apparently was deposited in a fresh water lake. Data derived by Upson[8] point to the same conclusions in regard to the nature of the sediments in which the fossils here discussed are found.

A theory of origin of the Latah sediments is described by Kirkham and Johnson[4] as follows:

> Westward-flowing drainage in mature valleys would be obstructed and ponded by lava flows advancing toward the mountains from a generally westerly direction along an irregular north-south front. Sediments brought down from adjacent mountains would be deposited in front of the flows at first, and as the ephemeral lakes rose in level and were filled up by deposition, the lakes would extend gradually to the west. The sediments would also thin to the west. Successive lava flows would result in a succession of similar phenomena, and consequently more than one sedimentary series would occur in the section. The final result should be a succession of lava flows alternating with sedimentary beds which lie partly in front of them, and partly interbedded with them. Thickness and area of the part which lay in front of the lava flows would vary greatly from place to place, but the thickness and extent of that part which became interberred would be more likely to show some uniformity. At all of the Idaho localities, where the relationships are clear, the evidence bears out the postulate.

Kirkham and Johnson state that field evidence in the Idaho localities has persuaded them to stand by this time-honored theory of origin although it was rejected by Pardee and Bryan for the Spokane area.

The original Latah flora as described by Knowlton contained 42 genera and 95 species of which 51 were regarded as new to science. All specimens examined were from the vicinity of Spokane, Washington and Coeur d'Alene, Idaho. In 1928 Berry[2] revised the flora of the Latah formation and added 57 species and 33 genera. In this latter paper fossils from an additional locality, Stanley Hill, two miles northeast of Coeur d'Alene, were studied.

In the last ten years investigators have reported other localities from which fossils assumed to belong to the Latah formation can be obtained. Kirkham and Johnson[4] list forty such localities within an area approximately 175 miles long and 75 miles wide. Although they include no descriptions of species, they do enumerate species that had not been reported from the Spokane localities. In 1932 Ashlee[1] published the results of his studies on some of the Latah formation in Idaho, and in this several species were added to those already listed by Berry, Knowlton, and Kirk-

*Research aided by a grant from The Northwest Scientific Association.

ham and Johnson. Olson[6] has enumerated several fossil localities in north central Idaho in Latah, Nez Perce, Clearwater, and Idaho counties. Most of these he infers are Latah in age and the majority of these are the same as listed previously by Kirkham and Johnson.

In 1936 Brown[7] published in the United States Geological Survey "Additions to some fossil floras of the western United States". This paper represents a partial revision of the floras represented in the collections of the United States Geological Survey and the United States National Museum. He has proposed many changes in the nomenclature of Knowlton, Berry, and others in the belief that these changes "express a more accurate taxonomic disposition of the species involved". Although Brown's study represents mainly a revision of nomenclature as far as the Latah of Spokane is concerned, seven new species from this region have been described. Several new genera have been added as the result of these synonymy studies.

The materials used in this study were obtained from road cuts along the highway between Juliaetta and Arrow Junction in Nez Perce County, Idaho. One locality (Kirkham and Johnson's station 27(?)) is approximately five miles south of Juliaetta, and a second is five miles farther on toward Arrow Junction (Figure 1). Both localities are on the right side of the highway.

Thus far in this work 35 genera, 42 species in 22 families of Spermatophyta have been recognized from these localities. Some specimens of Bryophyta and club mosses also have been found, but these have not been placed in any genus. Of the seed plants, none of the following genera was mentioned by Knowlton, Berry, Kirkham and Johnson, and Ashlee: *Abies, Picea, Thuites, Carya, Cedrela, Maytenus*(?), *Fraxinus, Vitis, Zelkova,* and *Philadelphus.* (Some of these are the result of Brown's changes of the nomenclature of Knowlton and others.) In addition to the above genera, the following species are new to the Latah flora: *Amelanchier dignatus* (Knowlton) Brown, *Acer septilobatum* Oliver, *Umbellularia oregonensis* Chaney, and undetermined species of *Sophora* and *Nyssa.* Besides these there are several leaves which as yet are unidentified with any available descriptions of western Miocene plants. Some of these doubtless will prove to be new genera for this area. In addition it has been impossible to identify numerous twigs, seeds, and fruits.

Figure 1. Second locality, 10 miles south of Juliaetta, Idaho. Sediments here are tilted.

The flora may be divided into three groups on the basis of distribution of the living equivalents, namely: (1) An eastern Asiatic element, (2) an eastern North American element, and (3) a western North American element.

THE ASIATIC ELEMENT:

Fossil Species.	**Living Equivalents.**	**Distribution.**
Alnus relatus	*Alnus japonica*	Japan
Betula fairii	*Betula luminifera*	China
Zelkova oregoniana	*Zelkova ulmoides*	Southwestern Asia
	Zelkova serrata	Japan
Hydrangea bendirei	*Hydrangea strigosa*	China
Sapindus oregonianus	*Sapindus mukorossi*	Eastern Asia
Viburnum lantanafolium	*Viburnum dilatatum*	Japan
	Viburnum erubenescens	China
	Viburnum lantana	Southeastern Asia and Europe

THE EASTERN AMERICAN ELEMENT:

Taxodium dubium	*Taxodium sp.*	Southeastern U. S. and Mexico
Carya egregia	*Carya ovata*	Eastern N. A.
Ostrya oregoniana	*Ostrya virginiana*	Central and eastern U. S.
Magnolia dayana	*Magnolia acuminata*	Eastern N. A.
Liquidambar californiaum	*Liquidambar styraciflora*	Eastern U. S.
Nyssa knowltoni	*Nyssa aquatica*	Southeastern U. S.

THE WESTERN AMERICAN ELEMENT:

Torreya bonseri	*Torreya californica*	West coast
Sequoia langsdorfii	*Sequoia sempervirens*	West coast
Alnus carpinoides	*Alnus tenuifolia*	Western states
Philadelphus pardeei	*Philadelphus lewsii*	Northwestern states
Acer septilobatum	*Acer circinatum*	West coast
Fraxinus denticulata	*Fraxinus oregona*	West coast

In addition to these there are some species whose living equivalents are fairly widespread, at least in the North Temperate zone.

THE COMPOSITION OF THE FLORA

Taxaceae
Torreya bonseri

Pinaceae
Abies sp.
Picea sp.
Pinus spp. (seeds and cone scales)
Sequoia langsdorfii (Brongniart) Heer
Taxodium dubium (Sternberg) Heer
Thuites sp.

Typhaceae
Typha (?) sp.

Salicaceae
Populus heteromorpha Knowlton
Populus fairii Knowlton

Juglandaceae
Carya egregia (Lesquereux) LaMotte

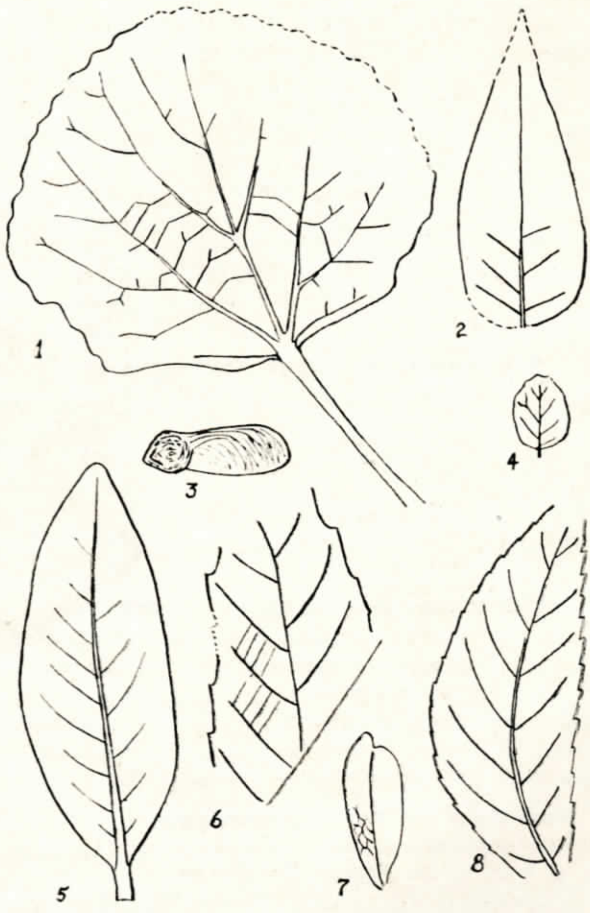
Betulaceae
Alnus corallina Lesquereux
Alnus carpinoides Lesquereux
Alnus relatus (Knowlton) Brown
Betula fairii Knowlton
Ostrya oregoniana Chaney

Fagaceae
Castanea orientalis Chaney
Fagus sp.
Quercus simulata Knowlton
Quercus payettensis Knowlton

Ulmaceae
Zelkova oregoniana (Knowlton) Brown
Ulmus sp. fruit.

Lauraceae
Umbellularia oregonensis Chaney

Magnoliaceae
Magnolia dayana Cockerell



(Drawings reduced about ⅓ in diameter from originals.)

PLATE I.

Fig. 1—*Vitis washingtonensis* (Knowlton) Brown.
U. I. Botany collection No. 100.

Fig. 2—*Fraxinus denticulata* Heer. U. I. collection No. 101.

Fig. 3—*Acer septilobatum* Oliver. U. I. Botany collection No. 102.

Fig. 4—*Philadelphus pardeei* (Knowlton) Brown.
U. I. Botany collection No. 103.

Fig. 5—*Umbellularia oregonensis* Chaney. U. I. Botany collection No. 104.

Fig. 6—*Zelkova oregoniana* (Knowlton) Brown.
U. I. Botany collection No. 105.

Fig. 7—*Maytenus* (?) sp. cf. *M. phyllanthoides* Bentham.
U. I. Botany collection No. 106.

Fig. 8—*Carya egregia* (Lesquereux) LaMotte. U. I. Botany collection No. 107.

Saxifragaceae

Hydrangea bendirei (Ward) Knowlton

Philadelphus pardeei (Knowlton) Brown

Hamamelidaceae

Liquidambar pachyphyllum Knowlton

Liquidambar californicum Lesquereux (fruit)

Rosaceae

Amelanchier dignatus (Knowlton) Brown

Leguminosae

Cercis spokanensis Knowlton

Sophora spokanensis Knowlton

Meliaceae

Cedrela pteraformis (Berry) Brown

Celastraceae

Maytenus (?) cf. *phyllanthoides* Bentham

Aceraceae

Acer septilobatum Oliver (fruit)

Acer sp. (leaf)

Sapindaceae

Sapindus oregonianus Knowlton

Vitaceae

Vitis washingtonensis (Knowlton) Brown

Cornaceae

Nyssa knowltoni Berry

Oleaceae

Fraxinus denticulata Heer

Caprifoliaceae

Viburnum lantanafolium Berry

Incertae Sedis

Carpites boraginoides Knowlton

CONCLUSIONS

The plants listed above from the two localities in north central Idaho indicate Miocene age and probably Latah. Whether these are older or younger than the Latah of Spokane, the writer is not prepared to state at the present time.

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Abstract

Pegmatite Minerals at the Kettle Falls of the Columbia

By **CHARLES D. CAMPBELL**

State College of Washington

A granitic pegmatite sill in the quartzites forming Kettle Falls swells to over ten feet in thickness, and pinches out to zero, the variations being irregular. Its minerals, in decreasing order of abundance, are orthoclase, quartz, albite, muscovite, tourmaline, garnet and beryl. The larger orthoclase crystals are six-inch ovoids, locally perthitic. These and the smaller crystals are coated with creamy albite which has turned crumbly with weathering. Gray vitreous quartz forms small irregular masses, and a later generation cuts all other minerals. Muscovite books up to two inches across are imbedded in the feldspars. Small black prisms of tourmaline are clustered locally; many are cracked and then healed with late quartz. Red trapezohedral garnets occur in most places; and in one nest near the east end of the lower falls, crystals over an inch in diameter were found. A few small pale-blue beryl crystals occur in a north-facing wall upstream from the large garnets. Only the late quartz, in fragile veinlets, is thought to be of later date than the deformation which strained, cracked and granulated the other minerals.

Significance of a Fossil Horse Tooth Found at Moscow, Idaho[1]

By VERNON E. SCHEID

Late in June, 1939, a lower cheek tooth of a horse was uncovered while digging the foundation for the Signal Oil Station at Main and 8th Streets, Moscow, Idaho. It was found about four feet below the surface. The earth surrounding the tooth was undisturbed and was identical in all characteristics with the "Palouse"[2] formation, as it is exposed in road cuts throughout the surrounding country.

The tooth (Fig. 1) is a lower left cheek tooth—whether a molar or premolar it is impossible to determine. When dug up, it was complete but the lower portion of the anterior root broke off later. The tooth is large and heavily cemented, so that the upper portion of the buccal surface slopes inwardly toward the grinding surface. The cement is lightly striated vertically and shows flat, horizontal, irregular bulges on the upper one-third of the buccal surface of the crown. As viewed from the posterior the tooth shows a slight curvature; the outer side being convex. All sides of the tooth are somewhat vertically grooved; the buccal side distinctly and the labial side very pronouncedly. An unusual feature of the section shown by the grinding surface is the small, oval conulid (see "a" of Fig. 1) near the middle of the anterior surface. Measurements of the tooth are recorded as follows:

Anteroposterior length	33 mm.
Transverse width	23 mm.
Height (vertical length)	75 mm.
Height of Crown	44 mm.

The tooth was examined by Dr. C. L. Gazin, U. S. Nat. Museum who writes[3] "that it seems to be very near the form Equus idahoensis. It is fully as large as in E. idahoensis but differs from this species in exhibiting a somewhat more modern pattern. I have no hesitancy, however, in regarding the specimen as of Pleistocene age rather than Recent."

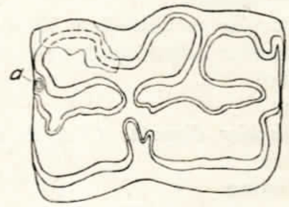

Fig. 1. Grinding surface of horse tooth from the "Palouse" formation, Moscow, Idaho. Natural size.

Fossils are practically unknown from the "Palouse" formation throughout the "Palouse country" of eastern Washington and the adjacent portions of Idaho. This fact lends added importance to the Moscow horse tooth as a clue to the age of the sediments. As noted above from a letter by Dr. Gazin, the tooth is near but apparently younger than E. idahoensis, which was first described by Merriam[4] from the Idaho formation. This formation has been studied and correlated by several workers. Merriam writes[5] that the Idaho formation "contains a fauna of a stage representing either the latest Pliocene or the earliest Pleistocene". Kirkham in his revisional study agrees[6] with Merriam. But Hay[7] would restrict the formation to the Pleistocene and suggests that the contained fauna "may justify the reference of the deposits to some part of the Nebraskan stage". Thus, it seems well established that the Idaho formation is early Pleistocene bordering on late Pliocene. The new species, Equus idahoensis, would of course have the same age. On the basis of the more modern enamel pattern, the horse tooth from Moscow may be considered at least slightly younger than E. idahoensis and therefore of post-Nebraskan age; if Hay's correlation of the Idaho formation is to be accepted.

An upper limit to age of the tooth is

not so easily obtained and can only be estimated after considering the geology of the "Palouse" formation. Since its definition by Treasher[8] the validity of the "Palouse" as a single formation and its position in the geologic column has been questioned by several workers. Treasher, himself, pointed out that the formation was composed of two phases: (1) a lower, well stratified and thinly-bedded loess and (2) an upper, massive silt formed from reworked material of the lower phase. Above both phases is the present fertile soil of the "Palouse country"; this Treasher considers to be a residual modification of the two underlying phases.

Most other workers have also recognized two phases in the "Palouse" formation. Bryan's study[9] nicely summarizes the known geologic and physiographic data of the formation. He also recognized two phases: an older phase, which composes the inner core of the Palouse hills and a younger phase above it. The older phase is composed of several types of sediments; including a well weathered and compacted glacial till. The younger phase is a thin veneer, 3 to 10 feet deep of loessial soil. The younger or upper phase was established by him as older than the Spokane glacial stage and younger than the "early" glacial stage of Bryan; the till of which, as previously noted, is contained in the older phase of the "Palouse" formation. This places the age of at least a part of the older phase as that of the contained glacial till which with the elephant bones[10] uncovered by Bryan caused him to consider the age of the older phase of the "Palouse" formation to be "pushed far back into Pleistocene time"[11]. More recently Culver[12] has argued that the "Palouse formation is an extension of the Ringold[13] formation of central Washington. He would restrict the term "Palouse" formation to mean only the agricultural soil of the "Palouse country"; that is, the surficial material, a few feet thick, formed as a reworked modification of the underlying "Palouse" or Ringold formation. Merriam and Buwalda[14] consider the Ringold formation to be Pleistocene rather than the latest Pliocene and imply that they favor the lower Pleistocene. If by extension this is accepted as the age of the formation at Moscow, it is seen to be near that of the Idaho formation of southwestern Idaho. However, whether the tooth was lodged in the upper or lower phase of the "Palouse" formation is not known. As shown by Bryan the upper phase of the "Palouse" formation is older than Spokane till but younger than still another but undated till contained in the lower phase.

Thus the determination of the exact age of the formation containing the horse tooth at Moscow must await additional evidence. Its geological location quite clearly places it as older than the modern, residual, reworked, surface soil (Palouse of Culver) that furnishes the fertility of this region. From admittedly scant paleontological evidence the formation is younger than Nebraskan and even if it should prove to be the upper phase of the "Palouse" formation, physiographic and geologic studies of similar deposits throughout the "Palouse country" have shown it to be older than the Spokane glacial stage. These limits suggest middle or lower middle Pleistocene time as the age of at least a part of the "Palouse" formation around Moscow.

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Reverse Versus Thrust Faults

By J. DONALD FORRESTER
University of Idaho, Moscow, Idaho

This note arises from a desire to urgently caution against the ambiguous employment and false interpretation of the word "thrust" in the geometric description and treatment of all high-angle reverse faults. The indiscriminate usage of "thrust" as a descriptive adjective, with no thought as to what the deforming stresses may have been, has crept into geologic literature and into the mental processes of numerous geologists. For example, in the well-assembled and concisely written text "Geology, Principles and Processes" by Emmons, Thiel, Stauffer, and Allison, which was recently revised (1939), the term thrust and reverse are loosely used. Figure 388 (page 358) illustrates, in geometric description, a normal fault as compared to a reverse fault structure, but the reverse fault has there been unsuitably labeled "thrust". Again, on page 359, it is inferred, if not stated directly, that thrust and reverse have synonymous meanings. Many other references of like nature can be cited, not only from textbooks of geology, but also from current geologic journals and periodicals.

Willis, in defining the terms normal fault and reverse fault, writes as fol lows:[1] "A fault which was the reverse of normal was a reverse fault. These old terms have outlived their usefulness and have gathered a number of misconceptions, but they are so firmly fixed in the nomenclature of geology that they must be continued in use, though we should try to avoid the false interpretations with which they are too often associated."

Regardless of whether high-angle and low-angle may constitute more suitable descriptive terms we are, as Willis believes, probably obliged to continue the use of the words normal and reverse in fault terminology. The fact that geology is not an exact science should not preclude the proper use of terms and descriptions, especially when certain designations have been made and defined. "Geology suffers accordingly, for loose language is the expression of loose thinking and leaves the reader in doubt as to the value of the observations which it records," Willis.[2]

Members of the Geological Society of America early realized the importance of standardization of fault nomenclature. This Society, in an effort to overcome ambiguity and inconsistency in the descriptive treatment of faults, appointed a committee in 1908 to study and formulate principles for the nomenclature of faults. The report of this committee, published in 1913, has become accepted as the authority of fault terminology. Reverse faults are therein defined[3] as fault structures, "Where the hanging wall has been raised relatively to the footwall," and further it is written,[4] "We recommend that the terms **normal** and **reverse** faults as defined be used purely for purposes of description and not for the purpose of indicating extension or contraction, tension or compression, vertical or horizontal forces." Thus it is apparent that the antonym of normal is reverse, certainly not "thrust", which by its connotation primarily suggests compression. In fact, this point is clearly stated by the Committee on Nomenclature where they list, as one of their guiding principles,[5] the desire "to make the classification (of faults) geometric and descriptive, not genetic, in order that a fault may be described so far as it may have been observed without any inferences as to the forces which produced it. For instance a so-called "thrust fault" may sometimes be formed without any compression, and a "tension fault" without any tension; the terms "thrust" and "gravity" faults . . . should only be used after the forces which produced the fault are understood . . . a dynamic system of classification will be in order when the dynamics of faults is better understood."

Because horizontal movement can, under certain conditions, give the appearance of normal or reverse faulting, even though there has been no vertical stress component during displacement, Nevin,[6] in defining a reverse fault, adds the qualifying adverb that the hanging wall has **apparently** moved up with respect to the foot wall. Willis[7] also qualifies normal and reverse fault terminology by the word **apparent**.

If we grant the premise, or at least assume, that the dynamics of faults are better understood today than they were in 1913, then still further evidence presents itself in support of the contention that "thrust" should not be used in lieu of, or interchangeably with, the term "reverse." Studies of the dynamic relations and the stresses involved in the formation of numerous horst structures indicate that, in many instances, these block like forms have been produced by actual uplift of the block; that is, by vertical uplifting stresses or central "up thrust" adjustments. If the faults which delimit the horst are the normal type, as is frequently the case, then the term "thrust" can be used conveniently to describe the manner of stress causing the resulting fault ridge even though the adjacent faults are of normal type. The particular structures should then be properly called thrust[8] normal faults. When the associated faults are reverse, and the center portion has been proven to be actively "up thrust", then the component structures, which bound the area, may be described as thrust reverse faults.

If "thrust" has a place in geologic terminology, that place is in the treatment of stress relations or in the presentation of dynamic principles. Webster[9] defines the geologic use of thrust as, "a compressive tangential stress in the earth's crust or the effect of such a stress; a thrust fault." Although a thrust fault is therein[10] given as, "when the angle between the horizontal and the plane of a reverse fault is small the fault is a thrust fault or an overthrust fault," this employment of thrust fault is technically not proper even in the geometric description of overthrust or underthrust faults. The term **overthrust** is recommended in lieu of "thrust" by the Committee on Nomenclature[11] when a reverse fault of low dip is being geometrically treated.

To the casual reader the title of this paper may have appeared quite naive. However, the writer is convinced that such a reaction, if experienced, was not directly induced by the title to the degree that it was from the widespread improper use of the term "thrust" fault. The foregoing discussion may be summarized as follows:

"Thrust" and "reverse" are not interchangeable in fault description.

The antonym of normal fault is reverse fault.

Low-angle reverse faults are either overthrust or underthrust faults when described geometrically.

"Thrust" should be used as an adjective to describe the fracture when the strain can be determined to have resulted through thrusting stresses.

The point may be raised that such a terminology is confusing and unnecessary. In the writer's opinion, it is certainly less confusing than the lax treatment now prevalent and, in addition, it coincides with the requirement some authors[12] now find for the use of the terms "thrust" or "upthrust".

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[1]Baily Willis and Robin Willis: **Geologic Structures Third Edition**, McGraw-Hill Book Company, Inc., (1934) p. 148.
[2]**op cit.**, p. 214.
[3]H. F. Ried, **et al: Report of the Committee on the nomenclature of faults**, Geol. Soc. Am., vol. 24 (1913) p. 177.
[4]**Ibid.**, p. 178.
[5]**Ibid.**, p. 164.
[6]C. M. Nevin: **Principles of Structural Geology**, John Wiley & Son, Inc., (1931) p. 83.
[7]**Op cit.**, p. 149.
[8]Nevin and Willis both use "upthrust" as perhaps a more suitable term.
[9]**Webster's New International Dictionary of the English Language Second Addition unabridged**, G. and C. Merriam Company (1936) p. 2638.
[10]**Op cit.**, p. 924.
[11]**Op cit.**, 5, p. 179.
[12]C. M. Nevin: **op cit.**, p. 106.
Baily Willis and Robin Willis: **op cit.**, p. 225-227.

Paleoecology of a Montane Peat Deposit at Bonaparte Lake, Washington

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This study is concerned with fossil pollen analysis of a montane, post-Pleistocene peat deposit in north central Washington. The specific location is at the north end of Bonaparte Lake in Section 9, T. 38 N., R. 30 E., on the Osoyoos Quadrangle in Okanogan County, Washington, about 15 miles sou.h of the Canada border. This area lies within the boundaries of Pleistocene glaciation which is in general correlated chronologically with the Wisconsin stage of the upper Mississippi Valley region (Flint, 1935). Bonaparte Lake is situated in the valley and near the headwaters of Bonaparte Creek which flows southwest, then west, and finally northwest to empty into the Okanogan River. The lake was apparently ponded by a terminal moraine or glaciofluvial sediments. Several small kettle ponds exist a short distance above the lake, while downstream the valley floor is largely covered with a sedge-meadow for several miles. The north and south margins of the lake are being encroached upon by hydrarch plant succession, but the lateral shores are steep and rocky and show little evidence of bog formation. The elevation of the lake is about 3600 feet above sea level. The surrounding area is exceedingly rugged, with steep slopes rising immediately to the east and west of the lake. Mt. Bonaparte, several miles to the west, is the highest peak in the vicinity and reaches an altitude of 7280 feet. The area lies near the western edge of the Northern Rocky Mountain physiographic province (Fenneman, 1931), and is usually spoken of as the Okanogan Highlands.

Forests in Adjacent Areas.

The peat deposit is located within the Canadian Life zone, which occupies a small, isolated area in this region because of its higher elevation than the surrounding area (Piper, 1906). The upper slopes of Mt. Bonaparte support the Hudsonian, surrounded by the Canadian zone. These are encircled by the Arid Transition (timbered) zone, which grades into the timberless portion of the same zone near the Okanogan River about 30 miles to the west. The timberless Arid Transition in turn grades into the Upper Sonoran Life zone in the Okanogan Valley. The combined area of the Canadian and Hudsonian zones is slightly greater than a township, with the peat deposit situated near the northeastern edge. Thus, three life zones exist in close proximity to the peat deposit, and are recorded therein by the pollen from their forests. The timbered Transition zone, however, comprises by far the largest part of this region.

The Canadian Life zone in the state of Washington is not well defined, but western white pine (*Pinus monticola*) is probably more restricted to and representative of this zone than any other tree (Piper, 1906). It is not, however, so abundant as in northern Idaho. In the Okanogan Highlands other conifers present, but not confined to this zone, include Douglas fir (*Pseudotsuga mucronata*), lodgepole pine (*Pinus contorta*), western larch (*Larix occidentalis*), lowland white fir (*Abies grandis*), Engelmann spruce (*Picea engelmanni*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). The Hudsonian, lying just above the Canadian zone, supports sparse forests of subalpine fir (*Abies lasiocarpa*), lodgepole pine, white bark pine (*Pinus albicaulis*), alpine larch (*Larix lyallii*), and mountain hemlock (*Tsuga mertensiana*). The timbered Arid Transition zone is characterized chiefly by western yellow pine (*Pinus ponderosa*) which usually occurs in pure, open stands because of its intolerance for shade. It is often associated with Douglas fir. Other trees in order of their abundance are lodgepole pine, western larch, lowland white fir, western hemlock, and western red cedar. The latter occurs chiefly on protected sites near stream courses. Broadleaf species which thrive locally on favorable sites in both the Transition and Canadian zones include cottonwood (*Populus trichocarpa*), mountain birch (*Betula fontinalis*), mountain older (*Alnus tenuifolia*), late alder (*A. sitchensis*), dwarf maple (*Acer glabrum*), and several species of willow. It is to be noted that lodgepole pine occurs in all three life zones, usually as a disclimax species invading areas that have been disturbed by lumbering and fire.

Clements' classification of the major North American vegetation climaxes includes most of the Okanogan Highlands in the larch-pine association of the coast forest (Weaver and Clements, 1938). Altitudinally, this forest lies between the subalpine zone and grassland formation and includes most of the Canadian and timbered Transition zones. The larch-pine forest is a transition type between the cedar-hemlock formation of the coast forest and the montane forest of the Rocky Mountains. Zon (1924) includes most of the Okanogan Highlands in the yellow pine-Douglas fir forest without differentiating the higher slopes as forested with spruce-fir, which exists immediately above the former on the eastern slope of the Cascades. The bunchgrass prairie adjoins the yellow pine-Douglas fir forest at lower elevations. The yellow pine-Douglas fir forest includes all of the timbered Transition and most of the Canadian zone, while the spruce-fir forest includes the remainder of the Canadian and all of the Hudsonian zone according to Zon's classification.

The ruggedness and relief of the adjacent terrain with its diversity of slope, exposure, soil, and climate, effects the existence of several associations, faciations, and consociations near the bog. This variation of environmental factors is also manifested by a large number of forest types within a relatively small area (Forest Type Map, 1936). Thirteen different forest types exist within a radius of ten miles about Lake Bonaparte. The greatest part of this area is covered with an upper slope type consisting of Douglas fir, white pine, lodgepole pine, western larch, Engelmann spruce, lowland white fir, and an occasional specimen of western hemlock. This type lies adjacent to the east shore and to both ends of the lake. The peat deposit actually is within, but close to the edge of this type. The next most widely spread type is yellow pine which is represented by four size classes. This type, consisting mostly of large trees, forms a zone along the western edge of the lake and then extends north, where it covers the valley. This type has a higher percentage of its component species than the former, and is strongly represented in the upper levels of the pollen-bearing sediments. An extensive area of lodgepole pine type occurs on the higher slopes to the west, and this species is also abundantly recorded in the peat deposit. Douglas fir types of several size classes are of next importance, and this species records next to the highest proportion of pollen in the uppermost horizon of peat. Others of lesser importance and occupying small, isolated areas include subalpine, upper slope, and pine mixture types, the latter usually consisting of up to 50 per cent of yellow pine. Life zones and climax formations indicate in a general way and in broad classifications the existing forests, but forest types point out in greater detail their composition and the relative proportions of the component species.

Climate.

Thornthwaite (1931) in his classification of the climates of North America designates this region as having a subhumid, microthermal climate, with deficient precipitation at all seasons. Thornthwaite's climatic provinces are based upon the relation between humidity, temperature, and seasonal distribution of precipitation. Small, localized areas with different climate within the larger provinces are not indicated, but if the above climatic factors are known the climatic classification for an area may be computed with certain formulae. It seems probable that the Canadian and Hudsonian zones at higher elevations on the slopes of Mt. Bonaparte would constitute a wetter climatic province than the surrounding Arid Transition zone. The mean annual precipitation at Republic, Washington about 18 miles to the southeast at an elevation of 2650 feet is 14.4 inches. At Irene Mountain, 5 miles to the east at an elevation of 2700 feet it is about 13 inches, and at Lemansky Lake, 22 miles to the west at an elevation of 2500 feet the precipitation is 17 inches. The annual precipitation at Bonaparte Lake is probably at least as much as the latter, as its elevation is 3600 feet and it is well within the Okanogan Highlands. The annual mean temperature at Republic for a period of 26 years is 43.6 degrees.

Characteristics of the Bog.

North of Bonaparte Lake are several kettle ponds, all of which support various stages of hydrarch succession. The summer of 1939 had little precipitation and the more shallow of these ponds were entirely dry. The first pond north was isolated from Bonaparte Lake, although the surface of the peat deposit indicates that the isthmus between the two is inundated most of the year. Near the shore of the lake and pond exists a submerged hydrosere consisting of almost pure stonewort (*Chara sp.*). Farther toward shore a floating hydrosere of yellow pond lily (*Nymphaea polysepala*) and pond-weed (*Potamogeton longchitis*) is present. This is followed in shallow water and on the bog by bulrush *Scirpus validus*), spike rush (*Eleocharis sp.*), cattail (*Typha latifolia*), and water smart weed (*Polygonum amphibium*). On higher ground on the margin of the bog grow mountain alder, mountain birch, and several species of willow, but apparently with no significant zonation.

Peat samples were obtained in several places near the shore of the main lake and the pond with a Hiller peat sampler at quarter meter intervals. The greatest depth noted was 3.25 meters. The organic peat and other pollen-bearing sediments are underlain with sand and gravel, through which the peat sampler was unable to penetrate. The lower meter consists of a whitish-gray

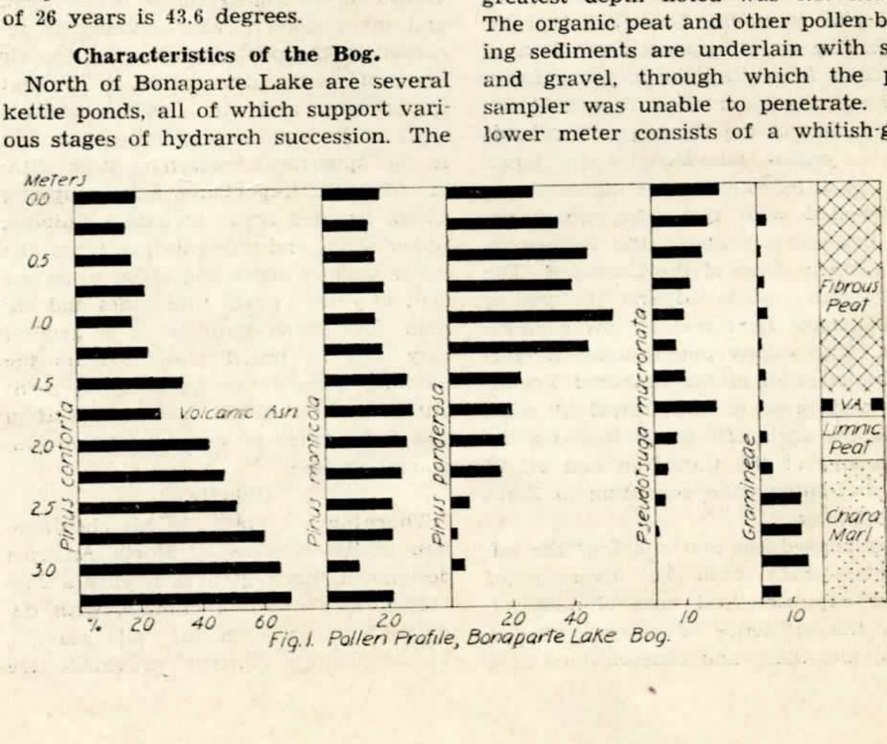

Fig. 1. Pollen Profile, Bonaparte Lake Bog.

marl formed from the remains of Chara which assimilates considerable calcium carbonate. At 2.25 meters this changes into a tannish-gray limnic peat, but with still a considerable amount of calcareous material present. At 1.85 meters this grades into a fine, fibrous peat which is present to the surface. A well-defined layer of volcanic ash occurs at 1.75 meters. Volcanic ash is present in many of the bogs in the Pacific Northwest (Rigg, 1939; Hansen, 1938, 1939a, 1939b, 1939c). In some bogs it occurs as a definite layer, while in others it is present in the form of crystals dispersed vertically through a half meter or more of peat (Hansen, 1940a, 1940b). The stage of hydrarch succession in the lake or on the bog at the time of eruption probably determined whether the ash is preserved as a layer or vertically dispersed. The layer of ash serves as an excellent chronological indicator, and it should be invaluable in correlating post-glacial forest succession as interpreted from pollen analyses of bogs in the several climax formations in the Pacific Northwest. It is presumably from the same eruption or series of eruptions of Cordilleran volcanoes, although a petrographic study would have to be made in order to verify this assumption.

Methods.

In preparation for study, about 2 cc. of peat or pollen-bearing sediment was boiled in a weak solution of potassium hydrate, strained through cheesecloth, centrifuged, washed several times, stained with gentian violet, and mounted in glycerin jelly. In the lower one and one half meter it was necessary to add several drops of concentrated hydrochloric acid in order to remove the calcareous crystals that otherwise obliterated the pollen and made their identification uncertain. The acid apparently had no effect upon the pollen grains, but it did eliminate all of the calcareous material with considerable effervescence. Exactly 150 significant pollen grains were identified from each level. The non-significant pollen was also recorded but not used in the computation of percentages. Non-significant pollen is that from plants which are not ocnsidered to be indicative of adjacent forest succession because of their localized occurrence on or near the bog (table 1). Those species recording less than 1.5 per cent of the total at any level are listed as 1 per cent in the table.

The differentiation of the pollen of *Abies*, *Pinus*, and *Picea* in the Pacific Northwest seems to present no difficulty. Their identification is based upon the size of the pollen grain, shape and position of the air sac on the cell, and the relative size of the air sac and cell. The separation of the species of *Abies* and *Pinus* is less easy, however, and their identification must be based largely on their size ranges. The following method was used for previous as well as the present study. Two hundred pollen grains of each species were measured and the size range determined. The modern pollen was fossilized with a weak solution of potassium hydrate, and mounted in glycerin jelly in order to simulate the conditions in preparing the peat pollen. This was found to be necessary because of the slight increase in size effected by the action of the potassium hydrate. The separation of the several species of pine pollen is the most difficult, and perhaps more subject to error than the other genera. *Pinus contorta* has the smallest pollen, and because it apparently does not overlap with that of *P. monticola* in size range, its segregation from the others seems to be fairly accurate. The pollen of *P. ponderosa* is larger than that of white pine, but there is some overlapping of their size ranges. The range of *P. albicaulis* is largely within that of white pine, but it also overlaps that of yellow pine. As there seem to be no other distinguishing characteristics, it is impossible to separate this species from the other two. White bark pine, however, is a timberline tree of the subalpine zone, and probably never was abundant during postglacial time. Pine pollen is far more abundant in bogs east of the Cascade divide than in the Puget Lowland. In the former region the pollen of white, yellow, and lodgepole pine constitutes the bulk of that recorded in the peat, and it is important that these species be separated in order to interpret postglacial forest succession and climate. In the Puget Lowland the pollen of Douglas fir and western hemlock represents the major proportion of the pollen recorded, except in the lower levels where lodgepole pine is usually the most common (Hansen, 1938, 1940a). Yellow pine is restricted chiefly to the east of the Cascades, although it does occur in rare instances on the gravelly, outwash plains near Olympia, Washington.

In Abies the size range of *A. amabilis* overlaps that of both the larger *A. nobilis* and the smaller *A. grandis*, so no attempt has been made to segregate this species. *A. grandis* is probably the most abundant, but it rarely records more than 10 per cent, while the total of fir pollen is seldom more than 15 per cent. *A. lasiocarpa* is the smallest of the fir pollen, but overlaps slightly with that of *A. grandis*. Its separation seems possible, however, by its air sacs which are larger in proportion to the cell than that of lowland white fir. The size ranges of *Picea sitchensis* and *P. engelmanni* overlap slightly, but as far as is known their geographic ranges do not overlap in Washington. The first is recorded in bogs west of the Cascades, while the latter is represented in montane bogs to the east, but not in considerable proportions. No attempt has been made to separate the pollen of *Larix occidentalis* and *L. lyallii*, nor that of *Tsuga heterophylla* and *T. mertensiana*. The latter species of each genus, however, occurs in the sub-alpine zone and are probably not recorded to any great extent in bogs at lower elevations. The pollen of *Pseudotsuga mucronata* is readily identified, but that of *Thuja plicata* apparently is indistinguishable from that of the species of *Chamaecyparis*, *Juniperus*, and *Taxus*. The pollen of these genera is fragile and probably not well preserved in peat.

In identifying fossil pollen, the size of the cell is noted, and if it is within the limits of overlap of other species, distorted in shape, or broken, it is discarded as an unknown. The proportion of significant pollen thus discarded varies from 5 to 12 per cent in this paper, which may or may not tend to invalidate the results of fossil pollen analysis.

Postglacial Forest Succession.

The pioneer, postglacial forests that invaded areas adjacent to the bog, as recorded in the earliest pollen-bearing sediments, consisted chiefly of lodgepole pine with some white pine. These species record 68 and 21 per cent respectively in the lowest level (fig. 1). Lodgepole pine in general seems to have been the chief initial, postglacial invader in glaciated areas of the Pacific Northwest, as is evidenced by pollen analyses of bogs that apparently had their origin soon after the recession of the glacier (Hansen, 1938, 1939a, 1939b, 1940a). In two bogs of which immediate postglacial origin is doubtful, lodgepole pine was not the most abundant conifer represented in the lowest pollen-bearing strata (Hansen, 1939c, 1940b). This suggests that the stage of forest succession may have progressed beyond the initial stage of lodgepole pine invasion, and it also corroborates the geological evidence that some postglacial time had elapsed before the origin of these two bogs. In this study, lodgepole pine gradually decreases to 27 per cent at 1.75 meters, and then fluctuates between 34 and 16 per cent from this level to the surface where it records 20 per cent. White pine decreases to 10 per cent at 3 meters, then gradually increases to 28 per cent at 1.75 meters, and then with slight fluctuation decreases to 18 per cent at the surface. Grass pollen is abundant in the lower levels, recording 6 per cent at the bottom, increasing to 15 per cent at 3 meters, recording 13 per cent at the next two levels, and then gradually decreasing to negligible proportions throughout the rest of the profile. A similar profile is shown by grass in a montane bog in northern Idaho (Hansen, 1939a), while in a bog near New Westminster, British Columbia, the highest percentage of grass is recorded in the level next to the bottom (Hansen, 1940a. The abundance of grass pollen may indicate the presence of tundra-like conditions which existed for some time upon the recession of the ice. On the other hand, it may suggest an initial grass invasion which was gradually replaced with forest with no climatic significance.

Yellow pine was seemingly absent in the pioneer forests, but appears in the 3 meter level where it records 4 per cent. The next level shows 2 per cent from which there is a gradual increase to 53 per cent at 1 meter, the highest proportion recorded by this species throughout. It diminishes with some fluctuation to 28 per cent at the surface. Yellow pine was the most abundant tree during the time represented from 1.25 meters to the surface. Douglas fir is absent in the lower levels, records 1 per cent at 2.75 meters, increases to 20 per cent at 1.75 meters, slightly decreases to 7 per cent at 1.25 meters, and makes a final increase to 22 per cent at the surface. Other conifers represented in limited proportions are western hemlock, Engelmann spruce, white and subalpine fir, and western larch. The latter is most abundantly and frequently recorded with 10 and 7 per cent in the upper two levels respectively (table I). Broadleaf species present are alder, maple, birch, and willow, with the first two most abundant. The increase in the number of sedge pollen from the bottom to top is correlative with the increase of sedge on the bog in more recent time. Thus, the forests existing in recent time within range of pollen dispersal to the bog, consisted chiefly of yellow pine, Douglas fir, lodgepole pine, and white pine, with their relative abundance in the order named. The proportions of these species as manifested by pollen analysis may be somewhat in agreement with those of existent forests. This is suggested by the distribution of the nearby forest types, and a cursory survey of the adjacent forests. It is realized, however, that their proximity to the bog, the relative amount of pollen produced, and the direction of prevailing winds during anthesis, as well as other factors influence their relative representation in the pollen-bearing sediments.

Climatic Considerations.

In recent papers on pollen analysis the writer has emphasized the possibility that other than climatic factors have been largely responsible for postglacial forest succession in the Pacific Northwest. Notwithstanding, he has made tentative climatic interpretations pending the analysis of a greater number of bogs and a more critical correlation of their pollen profiles. Certain conclusions from earlier studies may have to be revised in lieu of further investigations. The postglacial successional trend of a species in different climatic provinces and climax formations may serve to clarify its climatic relationships. It seems probable that there have been climatic trends during the estimated 25,000 years or so since the recession of the last ice-sheet, but the forest succession as interpreted from pollen analysis does not clearly depict these trends. In the Lake Region and the glaciated portion of eastern United States, pollen analyses reflect a rather definite climatic trend in the gradual disappearance of boreal tree pollen in the upper strata of peat deposits. The initial postglacial boreal forests migrated beyond range of pollen-dispersal to the bogs, and were replaced with those that thrive in more moderate climate. This is not true in the Pacific Northwest where the earliest recorded species may still exist extensively in the same climatic province with both climax and subclimax species represented in recently deposited peat. In some bogs a species records the highest proportion of pollen in both the lowest and highest levels, while others may show little fluctuation throughout the profile. The proximity of the Pacific Ocean undoubtedly has been a moderating influence in maintaining a more static postglacial climate than that of the Lake Region.

Many conifers in the Pacific Northwest seem to be better indicators of humidity than temperature, except subalpine species that do not exist in extensive stands. Temperature and moisture are probably the chief opposing factors of the environment, and their interplay and physiological compromise modify the influence of each other, while other factors in turn alter them. The relative tolerance for shade of the various conifers is one of the more important factors in controlling their successional relationships. This is indicated by the persistence of subclimax species where the trend of climax forest development is retarded, disrupted, or prevented from attaining its end. Fire, lumbering, and fungal and insect diseases are the chief agencies in effecting this course of events. The extensive geographic and climatic ranges of the species concerned and the overlapping of their ranges constitute some of the principal features that cause uncertainty in the interpretation of climatic trends from pollen analysis. The presence of a species in several areas may reflect different climates depending upon the ecological relationships of the species with which it is associated. On the other hand, a species may react differently in areas of similar climate if associated with different species, or edaphic and topographic conditions. The longevity and age of seed production would be important characteristics in regions of unstable environment. This would be especially true near the margin of a continental ice-sheet, where continual oscillation of the ice-front would create both changing climatic and edaphic conditions. Lodgepole pine would be at an advantage here, because of its early age of seed-bearing and its less exacting soil requirements (Larsen, 1929). The pioneer, postglacial invasion of lodgepole pine in the Pacific Northwest is perhaps largely due to unstable edaphic conditions, and its ability to migrate and re-establish itself before an oscillating ice-front. Its invasion of bogs in their climax stage is further evidence of its ability to thrive under edaphic conditions unfavorable for other species (Hansen, 1940a). After such conditions have been ameliorated by lodgepole pine forests, other species invade such areas and gradually replace the former because of its greater intolerance for shade. An increase in the percentage of pollen of a species in one bog may reflect a different trend of climatic fluctuation than its increase in another. This would depend upon the existent climate, its ecological relationship with the species or group of species it is replacing, and the climatic trend. Briefly, the successional status of a species is an expression of its ecological relationship with the others present, the existing environment, their relative demands upon the environment, and their physiological compromise. Climate may remain at an equilibrium, and forest succession may still proceed and reach a climax controlled largely by the biotic, edaphic, and physiographic factors.

Lodgepole pine is perhaps the poorest climatic indicator of the conifers recorded in the bog of this study. Its early invasion was probably due to its proglacial existence near the ice-margin, its non-selective soil requirements, and its early age of seed production. The recent presence of the ice in itself suggests a cool initial climate, but as far as precipitation is concerned, it is possible that a subhumid condition prevailed because of air currents moving off the ice. The existence of lodgepole pine in the wet climate of the Pacific Coast may indicate its tolerance rather than its demand for a moist habitat, for it seems to thrive only in sandy and well-drained soils. Neither is its occurrence on climax bogs indicative of a hydrophilic nature, because a bog may be physiologically dry so far as available water is concerned. The gradual and almost constant decrease in lodgepole pine throughout the profile is probably due to its inability to compete with more tolerant and longer lived species. It is the least permanent in the northern Rocky Mountain region (Larsen, 1929), and this is also true in the Pacific Northwest. The profile of western white pine does not show sufficient fluctuation throughout to warrant any climatic interpretation. That of western yellow pine is the most significant and shows the most definite trend. Its sharp increase from 4 per cent at 3 meters to 53 per cent at 1 meter suggests a drying of the climate. Yellow pine is more tolerant than lodgepole and less so than white pine, and thrives with less moisture than the latter. An increase in moisture would probably result in an increase in white pine because of its greater tolerance. The decrease of yellow pine from 1 meter to the surface may be the result of climatic change, normal forest succession under static climate, or interruption of succession by fire or disease. In the latter case, the destruction of yellow pine in adjacent areas would increase the proportions of other conifers, but not necessarily their actual abundance. Yellow pine is the most important commercial tree in this region, and its removal by lumbering in recent time may be responsible for its continued decrease at the surface. The analyses of two other bogs in the yellow pine forest, but nearer the timberless zone, indicates a gradual increase to a maximum which is maintained to the present (Hansen, 1939b, 1939c).

Douglas fir pollen is absent in the lower levels, but is present at 2.75 meters and reaches its highest proportion at the top. Its sharp decrease from the volcanic ash layer to 1.25 meters is difficult to explain. It might well represent an interruption of normal forest succession, because Douglas fir is more tolerant than either lodgepole or yellow pine and would normally replace them, other factors remaining at an equilibrium. The question always arises as to what extent the sources of error inherent in pollen statistics are involved in these minor fluctuations.

TABLE 1. PERCENTAGES OF FOSSIL POLLEN

Depth in meters	3.25	3.0	2.75	2.5	2.25	2.0	1.75	1.5	1.25	1.0	.75	0.5	0.25	0.0
Pinus contorta	68	65	60	51	47	42	27	34	23	18	22	18	16	20
P. monticola	21	10	21	21	24	26	28	26	18	16	19	16	14	18
P. ponderosa		4	2	6	16	17	20	23	45	53	40	45	36	28
Pseudotsuga mucronata			1	3	4	7	20	10	7	10	12	16	18	22
Tsuga heterophylla	1					1			1		1		1	1
Picea engelmanni		1		1			1	1	1		1	1	1	2
Abies grandis		1			2	4	2	2	1		1	1	1	1
A. lasiocarpa				1					2		1	1		1
Larix occidentalis	3	2	2	2	1	1		2				1	10	7
Gramineae	6	15	13	13	4	2	1	2	1	3	2	1	3	
Compositae		1	1	2	1									
Chenopod-Amaranth	1	1			1		1		1		1			
*Alnus**	12	9	1	9	8		1	3	5	3	11	8	4	2
*Acer**	1	6	14	22	27	11		1	2	3	1	2	4	3
*Betula**	1	2	3	15	7	2	4		3	2	8	4		1
*Salix**	4	2	1	1	3					5	2	3	3	
*Cyperaceae**	3	3	4	4	3	3	3	2	7	1	12	43	98	52
*Typha latifolia**	1	3	3	1	2	11	8	4	2	5	4	1	6	2
*Nymphaea polysepala**					3					1	1	4		

*Number, and not computed in the percentages.

Western larch is the most common of the other conifers, and its increase to appreciable proportions in the upper two levels may be the result of fire or fire or insects. Larch is resistant to fire because of its thick bark (Larsen, 1929) and the least subject to insects attack of the conifers (Keene, 1939). After several fires in close succession, it rapidly increases, but is gradually replaced because of its intolerance. It seems doubtful whether larch is a critical climatic indicator. The almost entire absence of western hemlock throughout the profile is similar to its status in other bogs located with the timbered Arid Transition zone (Hansen, 1939b, 1939c). Apparently this region was not sufficiently humid during the postglacial period for hemlock to thrive, as it needs considerable shade, moisture, and humus for germination and growth of its seedlings.

SUMMARY

Pollen analysis of a post-Wisconsin peat deposit in northern Washington, located within the Canadian Life zone, indicates that the pioneer forests to invade adjacent areas consisted chiefly of lodgepole and white pine, with some grass.

Lodgepole pine was gradually replaced to a large extent by yellow pine and Douglas fir, with a preponderance of yellow pine. White pine remained static and apparently was never predominant.

A decrease in yellow pine in the upper levels is difficult to attribute to climatic change. It may be due to normal forest succession or an interruption of succession by fire or disease. The continued decrease at the top may reflect the result of the recent lumbering operations in this region. The concurrent increase of Douglas fir in the higher levels, may suggest normal succession under static climatic conditions.

Climatically, the forest succession suggests a gradual drying and perhaps some warming to a maximum when yellow pine attained its maximum, from which time the climate has remained about the same.

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Pleistocene Deformation in the Olympic Coastal Region, Washington

By SHELDON L. GLOVER*

Recent work for the Washington State Division of Geology on the stratigraphy of the Pacific Coast border of the Olympic Peninsula has shown the existence in some places there, of marked Pleistocene deformation. Evidence of such movement is unusual enough to be of interest wherever it occurs, and this is particularly true of western Washington where, heretofore, folding in Pleistocene strata has not been recognized.

Many writers have touched on Pleistocene events in the western part of this state, but the most detailed accounts are those by Willis[1] and Bretz[2]. Both investigators recognized that the land had been uplifted and depressed during the Glacial epochs, but concluded that folding was not involved in such movements. This may be entirely correct for the areas that received almost exclusive attention; i. e., the region adjacent to Puget Sound. Excellent exposures there that permit detailed examinations to be made in countless places demonstrate the horizontal attitude of the sediments. It must be remembered, however, that these exposures are predominantly of Vashon beds, and that the scarcity of Admiralty sediments (using Willis' delineation of such material) permits only generalizations to be made on the structure of the earlier deposits.

On the coastal area of the Olympic Peninsula, Pleistocene sediments form the surficial deposits and, in some places, erosion has provided excellent exposures. These may be studied in the bluffs fronting the ocean and in banks of many of the larger streams. It is evident that two series are present. One, much older than the other and presumed to be early Pleistocene in age, is here termed the Taholah formation; the younger series, probably of late Pleistocene age, is here termed the Queets beds. From the available evidence, they are thought to correlate with the sediments of Admiralty and Vashon age, respectively, of the Puget Sound region.

The Queets beds, as might be expected, if they are the correlatives of the Vashon sediments, have undergone no known diastrophic disturbance. In some places they have been involved in large-scale block landslides and so give the appearance of local deformation. Also, minute but well-marked faulting and minor warping occur, but such effects have resulted from local adjustments to gravitational sags.

The Taholah formation, too, is mostly horizontal, and throughout great areas shows little, if any, inclination other than that due to primary dip and cross bedding, such as characterize sediments deposited from over-burdened streams. However, there are places where these beds are deformed, and further investigation will doubtless show more evidence of such movement in widely separated regions. One outstanding example is in the Taholah-Moclips vicinity where a sedimentation phase of the Taholah formation occurs that is quite distinct from the usual type. In this particular area the sands, gravels, and occasional clays were deposited in a subsiding basin, presumably an estuary, and so accumulated to a thickness far greater than is known elsewhere on the coast. Detailed sections of as much as 475 feet have been measured, and the persistent structural attitude of scattered exposures indicates that the total thickness of the formation is in excess of 1,500 feet. Individual beds of relatively well-assorted sand many be as much as 75 feet thick, though moderate thicknesses are the rule. The materials are unconsolidated, as contrasted to the Tertiary strata of

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the vicinity, but the sands and gravels are weakly to firmly cemented by iron oxide so that exposures offer sufficient resistance to erosion to attain vertical faces above the cutting agent.

The strata are well exposed in places along the Moclips River and there have been folded into a broad asymmetrical anticline that trends northwesterly. Dips on the west flank are as steep as 42 degrees; on the east flank they are in the amount of 10 to 15 degrees. It is of interest to note that the presence of this structure was doubtless the reason for an oil exploration program conducted by the Standard Oil Company of California in about 1920. Two test wells were drilled in this vicinity and reached a reported depth of approximately 4,000 feet.

Another series of exposures which provides good evidence of Taholah deformation and shows the relationship of that formation to the older Quinault rock and the younger Queets beds is in the vicinity of Wreck Creek. South of the creek a mile or so are occasional poor exposures that indicate the beds there are virtually horizontal. At 2,000 feet south of the creek they have a small but definite easterly dip; this is shown in an old railroad cut that exposes 15 feet of Taholah sand, underlain unconformably by some 30 feet of Quinault sandstone and overlain by 15 feet of horizontal Queets gravels. Exposures north from there to Wreck Creek are fairly continuous and show the strata striking nearly east and steepening to a 45 degree nor.h dip in the bank of the creek. This general trend continues to the axis of the fold, approximately 2,000 feet north cf the creek; beyond that the easterly trend is maintained, but the dip is southerly to as much as 22 degrees in the exposure farthest north. The structure here is that of an asymmetrical syncline, plunging easterly at an angle of six degrees or so, and conforms with an axis of anticlinal folding that trends through Point Grenville.

A third, and more spectacular, series of exposures is in the south bank of the Quinault River, southeast of the Indian village of Taholah. Here erosion has cut through the Queets beds in many places, exposing well-stratified thick beds of iron-stained sand and gravel for nearly two miles along the river. One-half mile from the village the series crops out in a high bluff where a stratigraphic thickness of 230 feet of sediments strike N. 5° E., and dip 30° S. E. For 4,000 feet upstream the exposures are poor, but such data as are available indicate a remarkable persistence in attitude to as far as the sharp bend in the river near the center of sec. 6, T. 21 N., R. 12 W. The northerly course of the river in this section appears to have structural control, and massive Taholah gravel is exposed in the left bank. Only Quinault sediments are exposed for the next thousand feet or so upstream from this stretch, and though the juncture of the two formations is concealed, the anomalous relations indicate that the two series are in fault contact.

The small area of older rocks is characterized by extensive landslides, and nothing definite is known of the structure. Profound disturbance, however, is indicated by the sheared and broken condition of shale masses in the nearly black mud that has resulted from their disintegration, and by flexures from 0° to 45° in non-disintegrated masses not over 30 feet across that may or may not be in place.

The Taholah formation is again exposed for 3,000 feet upstream from the east boundary of the area where the older rocks crop out. The contact here is remarkably well exposed and shows that the Quinault formation has been faulted up through the thick early Pleistocene cover. Erosion has stripped the sheared and easily weathered shales from the fault surface and left the Taholah series standing nearly vertically, high above the adjacent shales. This surface trends N. 40° W. and dips 78°

S. W. There are no indications of parallel breaks or of the development of a pronounced fault zone, but patches of mashed shales, a few inches thick, adhere to the fault plane.

The younger sediments, chiefly sands, on the east side of the fault are only weakly cemented by iron oxide, yet they form a cliff nearly 150 feet high. These strata strike N. 60° W. and dip 70° N. E. at the fault; this attitude gradually changes in 100 feet or so to a strike of N. 40° W., 40° N. E., and at the east end of exposures, 3,000 feet beyond the fault, the dip has decreased to 6° and the strike is N. 15° W., conforming rather closely to the regional trend in this general vicinity. Horizontal Queets beds, undisturbed by the movements that affected the earlier formations, overlie this whole area.

The deformation along the Moclips and Quinault rivers was described by Lupton[3] in 1914, and two years later Weaver[4] mentioned the conditions prevailing on the Quinault River. However, both investigators believed the folded early Pleistocene beds to belong to the Quinault formation and variously estimated their age, in consequence, as Miocene to Pliocene. Only the flat-lying surficial gravels (the Queets beds) were accounted as representing Pleistocene sedimentation. Presumably, Lupton thought the up-faulted block of Quinault formation to belong to the "supposed Cretaceous" series of Arnold[5]; while Weaver definitely places it in that category when he describes it as belonging to the "Hoh formation".

The attitude of the exposures on the Moclips and Quinault rivers indicates an axis of folding roughly parallel to the coast as the major structural control of the Taholah formation in this immediate area. Such deformation is in accord with the dominant folding that affects the older rocks and extends far to the north in the region adjacent to the coast. A transverse fold, the Wreck Creek syncline, has been impressed on the regional structure, and it is reasonable to assume that others exist. If exposures were available, it would probably be found that relics of the folding that produced the Grenville anticline and bordering Quinault syncline also affected the Taholah sediments. This deformation, therefore, appears to be due to recurrent movements along certain lines of weakness that persisted through the early Pleistocene but which have been inoperative since that time.

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Abstract

Addition of Feldspar to the Kettle Falls Quartzites

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The quartzite formation at Kettle Falls is traversed by a pegmatite sill, but has received little or no feldspar. A few miles to the west, in Hoodoo Canyon, some ten per cent of it has been replaced by rounded orthoclase crystals. These lie along and parallel to small healed fissures cutting across the schistosity of the quartzite at right angles. Still further to the west, all quartzites, whether correlatives of the Kettle Falls quartzite or not, contain substantial proportions of orthoclase and micas, reflecting their nearness to the underlying Colville batholith.

Abstract

A Phosphate Pegmatite From Eastern Latah County, Idaho

By VERNON E. SCHEID and R. M. ALLEN

A pegmatite dike, containing an assemblage of relatively rare phosphate minerals, has been found in the Mica Mountain region of eastern Latah County, Idaho. The pegmatite occurs in rocks of the pre-Cambrian Belt series that were metamorphosed to schists and gneisses by the intrusion in late Cretaceous time of the granitic Idaho batholith.

Intrusion of the pegmatitic material into the schistose country rock involved both injection and replacement. The pegmatite, which was originally typically graphic granite, has been subjected to periods of intense silicification, albitization, tourmalinization, and finally phosphate mineralization. Until the introduction of the phosphate minerals, the pegmatite was identical with many others in the region.

The minerals of the magmatic stage are quartz, microline, and muscovite. Through the action of ascending hydrothermal solutions, they were replaced in successive stages by: (1) quartz, which was, however, active throughout the entire intrusive period, (2) albite, (3) muscovite, (4) tourmaline, and lastly the phosphate minerals, (5) strengite, (6) vivianite, (7) triphylite-lithiophilite, and (8) salmonsite(?).

Abstract

Correlation of Some "Latah" Beds of Nezperce County, Idaho

By R. H. UPSON
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A fossil flora collected from exposures of "Latah" beds near Juliaetta, Arrow Junction, and Fir Bluff Station, Nezperce County, Idaho, is similar to that found in type Latah beds near Spokane and Republic, Washington, thus strengthening earlier correlations. Most of the exposures of the sediments, intercalated with the Columbia basalts, are in place and not in landsilde blocks. The occurrence of crossbedded sandstones interbedded with the fossiliferous clay layers indicates that the sediments are not wholly lacustrine, but in part fluviatile in origin.

Abstract

Pleistocene and Recent Normal Faulting in Southern Colorado

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Several small fault scarps, or scarplets, in alluvium have been discovered at and more or less parallel to the west base of the Sangre de Cristo Range in the Southern Rocky Mountains of Colorado and New Mexico. The presence of the scarps not only demonstrates the existence of recent fault movements in the region, but also supports previous postulates of Pleistocene movement. Thus, the region appears to be related tectonically to the Great Basin and other areas of Pleistocene and Recent normal faulting.


[H+]=5.6x10-6
log 341.73
pH=5.6
log 341.3
B.p.105°C
ARSENIC TRIOXIDE
ANALYTICAL REAGENT
¼ LB
POISON
MALLINCKRODT CHEMICAL WORKS