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ANALYSIS OF CRUSTAL CHANGES IN THE COLUMBIA PLATEAU AREA
FROM CONTEMPORARY LEVELING AND TRIANGULATION MEASUREMENTS*

MASTER

by

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ABSTRACT

ANALYSIS OF CRUSTAL CHANGES IN THE COLUMBIA PLATEAU AREA FROM CONTEMPORARY LEVELING AND TRIANGULATION MEASUREMENTS

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Geodetic data of the Columbia Plateau area of southeastern Washington and northeastern Oregon was analyzed to assess historical changes in first order leveling and triangulation networks that may relate to changes in the crustal structure.

Review of the first order leveling data supports the theory of weak tectonism that appears to have continued unchanged since early Cenozoic. A gradual basining is postulated that is proceeding at an average rate of 1 mm/year.

Analysis of position error vectors on triangulation stations in the central Columbia Plateau area did not show any positive evidence for systematic horizontal displacement.

OBJECTIVES

An analysis of geodetic data, in the Columbia Plateau area of southeastern Washington and northeastern Oregon was made to determine if contemporary historical changes in the network could be related to regional geologic structure or possible tectonic activity.

Geological background for this study is detailed in "A Study of Reported Faulting in Pasco Basin," by R. E. Brown,⁽³⁾ presented at 1969 meeting of NWSA. That report covers previous work on geotectonics of the area, evidence from field investigations at certain key but controversial sites of reported faulting, and relation of the data from studies in limited areas to the total geologic picture of the Pasco Basin.

This paper presents an analysis of the geodetic data available for the Columbia Plateau.

Because the leveling and triangulation data are of different character that call for different types of analyses, they are discussed separately.

SUMMARY AND CONCLUSIONS

An analysis of leveling data in the Columbia Plateau supports the theory of a very weak tectonism that appears to have continued essentially unchanged since early Cenozoic time (60 to 70 million years). A gradual basining, postulated from the leveling data available, is proceeding at an average rate of 1 mm/year. The rate of movement in the Columbia Plateau is comparable with other measured areas of minor or negligible crustal movement.

No evidence could be found for any contemporary vertical movement that would be associated with known or postulated fault systems.

An analysis of position error on triangulation stations in the Columbia Basin area did not show any evidence for either horizontal displacement or systematic movement. An apparent south-southwest alignment of direction in error vectors in the Walla Walla-Pomeroy area cannot be related to any known local or regional tectonics.

VERTICAL CRUSTAL MOVEMENT

Figure 1, page 3, shows the leveling data available in eastern Washington and Oregon. Four 1st order lines had resurveys in whole or in part,--Seattle to Pasco, Pasco to Spokane, Pasco to Ontario, Oregon, and Pasco to Portland, Oregon. Other shorter 1st order lines were utilized that included only a few points or had relevelings that were second-order or higher in accuracy.

The four 1st order lines used had all been surveyed at different times and from different directions and, therefore, there was no one point that could be considered constant or absolute. Since the purpose of this study was to investigate relative changes, it was decided that the entire line from Seattle to Pasco would be held constant and all other lines adjusted accordingly. This required an assumption for the area where the three other major lines connect near Pasco that any observed movement was absolute and did not change rate with time.

Figure 2 is the resultant vertical velocity contour map, superimposed on a structural trend map of the Columbia Plateau. Vertical velocity is simply the difference in elevation over some period of time divide by the time interval.

TEMPORAL AND SPATIAL
VERTICAL VELOCITY MOVEMENT

C1 - 1mm/year

FIGURE 2. ISOLINES OF TEMPORAL AND SPATIAL VERTICAL VELOCITY MOVEMENT, SOUTHEAST WASHINGTON AND NORTHEAST OREGON

The Seattle-Ellensburg-Pasco line, which was not corrected in any way from the raw field data, shows perhaps the only unbiased results. No analysis was made west of Ellensburg. The maximum rate of vertical change observed was about -3 mm/year in the area around Selah. The average rate for the entire line from Ellensburg to Pasco would be -1 to -2 mm/year. The average rate of change from Yakima to Pasco, is less than 1 mm/year.

For the Pasco to Spokane line, the maximum rate of change than can be substantiated is approximately -3 mm/year north of Ritzville. The average velocity rate for the Pasco to Spokane line is about 2mm/year or less. From Connell to Pasco the rate is less than 1 mm/year.

Data for the Portland to Pasco line is perhaps the most consistent and accurate. This is because of past requirements for the dam sites along the Columbia River. From The Dalles to Pasco, the average rate of velocity is less than 1 mm/year. Maximum displacement occur near Umatilla where 33 mm in 22 years was found.

Velocity values for the Pasco to Ontario, Oregon section, are comparable with the others in the Pasco Basin until south of Pendleton, being less than 1 mm/year. From Pendleton south, the movement rate increases to 5 to 6 mm/year near La Grande and 8 to 10 mm/year near Ontario.

The shape and value of the isolines in Figure 2 are based in part upon knowledge of the structural attitudes and geomorphic forms that would influence crustal movement, if in fact vertical crustal movement had occurred to any degree. This was necessitated by the low density of data in the geographic area covered. The general form of the contours appears fairly flat, particularly north of the Columbia River, with a general decrease or sinking to the south. This gives evidence of a low velocity of vertical movement throughout the northern Columbia Plateau in both Washington and Oregon.

Where the lines cross areas of structural discontinuities such as faults, folds, monoclines, etc., the data does not provide evidence for any significant displacement or gradient increase during contemporary times. One exception is in the area of Wallula Gap or Hunts Junction slightly south and east of Pasco. Being a convergence point for all four lines, the data points are more numerous and much closer

spaced. Velocities in this area are in general the lowest of any observed; about +0 to 0.5 mm/year. This is particularly significant in view of the fact that Wallula Gap is just slightly west of the only area (Walla Walla, Milton-Freewater) that has been positively identified with earthquakes and recent crustal movement. The Wallula Gap area is also a critical locale in regards to the proposed Olympic Wallowa Lineament which is traversed by a monoclinial flexure or fault(?) that has been suggested to indicate contemporary tectonic activity. Evidence from this study does not support either the existence of or contemporary activity on the Olympia-Wallaowa Lineament.

A question has been raised as to whether or not the man-made reservoirs on the Columbia River between Wallula and Portland have a loading effect on the crust. Data from the level lines that traverse this area, dating back to the 1920's indicate a moderate uplift at an average rate of approximately + 1 mm/year along the Columbia River east-west anticlinal system and into the Cascade Mountains, with a small settlement in the Umatilla Basin area, a synclinal basin.

With the exception of the ~~main~~ ^{level} line from Hunt's Junction to Ontario, Oregon, abnormal rates of movement are only seen on lines that were of second-order accuracy, lines with very short (2 to 3 years) time intervals between releveing, or lines run in one direction and not tied back into the main traverses. For example, the lines from Spokane to Omak, Davenport to Orondo, and Davenport to Trinidad all show quite high values of positive vertical movement. In a qualitative sense, this data may represent the response of the area to continued uplift of the Okanogan Highlands, the Wenatchee Uplift, and locally the Grand Coulee flexures. In a quantitative respect, it is difficult to imagine that a rate of positive displacement averaging + 3 mm/year could be occurring around Odessa during contemporary times without other evidence. Similarly, the line from Sprague to Pullman shows a very small uplift near Sprague and a very large settlement at Pullman. While the direction of these events is plausible, the magnitude cannot be supported by fact.

A recent paper by R. E. Brown (1969) discusses rates of movements of the basalt in the Pasco Basin area. His conclusions, based primarily on geomorphic and geotectonic evidence during recent and geologic periods, are that the deformation rate has been approximately 1 ft/5000 years. In this same report, Brown discusses the

deformation rate of the Cascades determined by others as about 1ft/1000 years. The average contemporary vertical movement rates indicated by this study are about 1 to 2 orders of magnitude greater. This could suggest an accelerated vertical movement rate from recent to contemporary time. Several studies, particularly, Gzovskiy and Nikonov (1968, op. cit.), present evidence indicating that the velocities of recent movements determine more precisely than do those of contemporary movements of the earth's crust, since they are free from secondary short-term exogenic and endogenic fluctuations.

Triangulation in areas of moderate to strong tectonism, triangulation networks can be established to record horizontal components of crustal movement over relatively short time intervals. In areas of weak or negligible tectonism, the slight amount of movement that may occur over some short period of contemporary time is usually less than the error inherent in measurement techniques. A requirement that appears to be necessary before any triangulation network can be used as a tool to measure horizontal crustal changes is indicated by the results from the California studies. That is, a surface discontinuity or relection of the discontinuity must be present and active in order to make reliable measurements over short periods of contemporary time. Also, where horizontal components of crustal movement have been measured by trangulation networks, the effects have not been seen at distances greater than 10 to 15 km from the fault.

Figure 3, ~~page 8~~, shows the triangulation data that is available in eastern Washington and Oregon. It would appear that the area is well covered except for some of the more mountainous regions such as the Cascades. It was found that several networks are not classified as first-order and none of the networks have been resurveyed. However, where two different triangulation networks meet, multiple observations are available on the stations common to both networks. Also, the time interval between some of the surveys is long enough to have measured some horizontal movement, if it occurred, and if the magnitude was greater than the standard error of observations.

This study concentrated on the area encompassing the proposed Olympic-Wallowa lineament, a surface alignment of physiographic and topographic features that extend from the Olympic Peninsula in western Washington across the Columbia Plateau and into southern Idaho. Most recent investigation indicate that the Olympic-Wallowa lineament does not exist as a through-trending, near surface structural or tectonic feature in the Wallowa Gap to Rattlesnake Hills segment of the Pasco Basin. Deep-seated structures may exist along the so-called lineament but their nature, orientation, continuity, whether they are in face related in any way to a lineament, and whether they are of any tectonic significance, can only be inferred. If the Olympic-Wallowa lineament does exist as an active system, either deep crustal or surficial, there is general agreement that the predominant movement would be horizontal and most probably left-lateral (McKee, 1967; Yates, 1967; Greenwood, 1968; Danes, 1964).

Figure 4, ~~page 10~~, is a map compilation of error vectors determined from simultaneous adjustment of the five triangulation nets chosen for this study. The magnitude of the error vectors has no direct relationship to the absolute magnitude of any possible horizontal crustal movement. Except for one correction between station Page-Hunt, position discrepancies were all less than the magnitude of error inherent in the measurement system. A supplementary re-adjustment of station Page, assuming all other stations to be stable, did not change the results.

It can be noted that there is almost complete randomness in the direction of the error vectors in many areas. One exception is an apparent alignment in the Walla Walla to Pomeroy area. A possible explanation is that there is a local crustal basin in the Walla Walla area that is sinking. Vertical data on the Sprague to Pullman line, already discussed, tends to support this theory by showing an abnormally high rate of sinking.

All of these factors lead to the conclusion that existing triangulation data do not provide evidence of horizontal displacement in southeast Washington or northeast Oregon.

SOUTHEAST WASHINGTON
NORTHEAST OREGON
POSITION SHIFT VECTORS FROM
COMBINED TRIANGULATION SCHEMES

FIGURE 4. POSITION SHIFT VECTORS OF HORIZONTAL CHANGE, SOUTHEAST WASHINGTON AND NORTHEAST OREGON

SUMMARY AND CONCLUSIONS

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