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'85 APR 30 A11:05

23 April 1985

WM Record File 101

WM Project 10
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Ms. Kristin Westbrook
Mail Stop 623-SS
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Ms. Westbrook:

Ms. Linda Lehman has requested that EWA, Inc. supply you with a copy of an EWA technical document titled "Critical Assessment of the Tectonic Stability of the Reference Repository Location" in regard to the BWIP project. Should you have any comments or questions regarding this document, please feel free to contact me at (612) 559-3706.

Sincerely yours,
EWA, Inc.

Kenneth Shimko

Kenneth Shimko
Senior Geological Engineer

KS/kj

enclosure

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In the draft Environmental Assessment, the DOE was unable to determine whether or not the Hanford site complies with the tectonic guidelines of DOE 10 CFR 960 due to an incomplete understanding of the tectonic character of the Hanford area. The DOE speculated that the Hanford site would comply with DOE final siting guidelines based on BWIP's work discussed in a collection of reports edited by Caggiano and Duncan (1983), "Preliminary Interpretation of the Tectonic Stability of the Reference Repository Location, Cold Creek Syncline, Hanford Site". A critical review of Caggiano and Duncan's report reveals problems with their assessment of the site's tectonic stability, specifically, the determination and interpretation of deformation rates. These deformation rates and subsequent interpretation are presented in two reports, Reidel et al. (1983) "Constraints on Tectonic Models as Provided From Strain Rates" and Rohay and Davis, (1983) "Contemporary Deformation in the Pasco Basin Area of the Central Columbia Plateau". These reports are discussed more fully below.

The tectonic stability of the Hanford area must be addressed with regard to DOE guidelines. The following unfavorable tectonic conditions, if determined to be present at the site, would directly affect the status of the Hanford RRL with regard to DOE guidelines:

1) Structurally unstable tectonic blocks and tectonic boundaries,
2) Faults or other geologic structures that have been active in Quaternary time or that have the potential to

PRELIMINARY

TO: Hanford File, Task II.2.B.iv

FROM: K. Shimko, V.V. Nguyen, J. Ryan /EWA, Inc.

SUBJECT: Critical Assessment of the Tectonic Stability of the Reference Repository Location

DATE: March 31, 1985

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## Introduction

The U.S. Department of Energy's (DOE) Final Siting Guidelines for Nuclear Waste Repositories (10 CFR 960) contain Pre-closure and Post-closure Tectonic guidelines. These guidelines require evaluation of the tectonic character of a nuclear repository site. This is being accomplished at the Hanford site in a 6-stage plan:

1) Compilation of geologic and geophysical data pertinent to the tectonic evolution of the Columbia Plateau.
2) Integration and interpretation of the data.
3) Additional data collection where the preliminary evaluation shows a need.
4) Evaluation and/or development of conceptual tectonic models based on steps 1 through 3.
5) Application of the above interpretations conjunctively with a selected conceptual model to test the validity of the corresponding constraints, and hence reduce the number of physically acceptable tectonic models.
6) Application of the identified set of tectonic models and assess various features that could have an effect on the stability of the reference repository location.

Currently, BWIP is engaged in Step 4 of this plan.

rupture during the repository containment period,

3) Historic earthquakes of a size that could, if repeated, affect the performance of the engineered and natural barrier to contain radionuclides,

4) Seismic zones with a higher rate of occurrence of earthquakes compared to the surrounding area or with the potential of more frequent, significant seismic events in the future,

5) Rapid uplift or subsidence rates that could compromise repository integrity or lead to increased erosion that could jeopardize isolation,

6) Quaternary volcanism, the potential for renewed volcanism, or a high geothermal gradient.

To address the future tectonic stability of the RRL, one must examine the past record and attempt to predict the deformation pattern. Therefore, an understanding of past deformation processes is important to determine the present tectonic setting of the RRL.

The strategy of BWIP's work to date is correct, perhaps, but many of their conclusions are not based on well-founded quantitative results, especially with respect to determining rates of deformation.

The deformation rates calculated by BWIP are calculated relative to a reference point, i.e., the Palouse paleoslope east of the Columbia Plateau. This slope is a gentle westward-tilting feature developed in the early Miocene. Swanson and Wright (1976) suggest the paleoslope's angle was maintained by slow westward tilting. BWIP scientists state that this regional tilting has been constant relative to the emplacement of the Columbia basalt flows. The paleoslope's position is linearly extrapolated to the point of interest and used as a reference or zero point from which uplift and subsidence are calculated (see figure 1). The ramifications of the use of the paleoslope as a reference point are discussed in this report.

It is important to determine if decoupling is occurring at the Hanford site. Decoupling refers to separate deformation mechanisms operating in two layers of rock, the Columbia River basalts and the rocks below these basalts. A two-layer decoupling model (basalt layer and rocks-below-basalt layer) restricts the extrapolation of regional structures into and under the Columbia Plateau to observed relationships. If deformation in the Columbia Plateau is occurring due to structures below the basalts, then the Columbia River basalts will probably respond more directly to activity associated with regional structures. Modeling of the deformation mechanisms requires assumptions regarding a thick-skin (one layer) versus thin-skin (two-layer) tectonic model.

## I. Calculating Long Term Low Average Rate of Strain

An average rate of uplift and subsidence is determined for the Columbia Plateau based on geological, geophysical, and seismic evidence.

As stated in Reidel et al. (p.5-7, 1983), two methods were used to calculate uplift/subsidence:

1) The measured thicknesses of basalt flows that occur

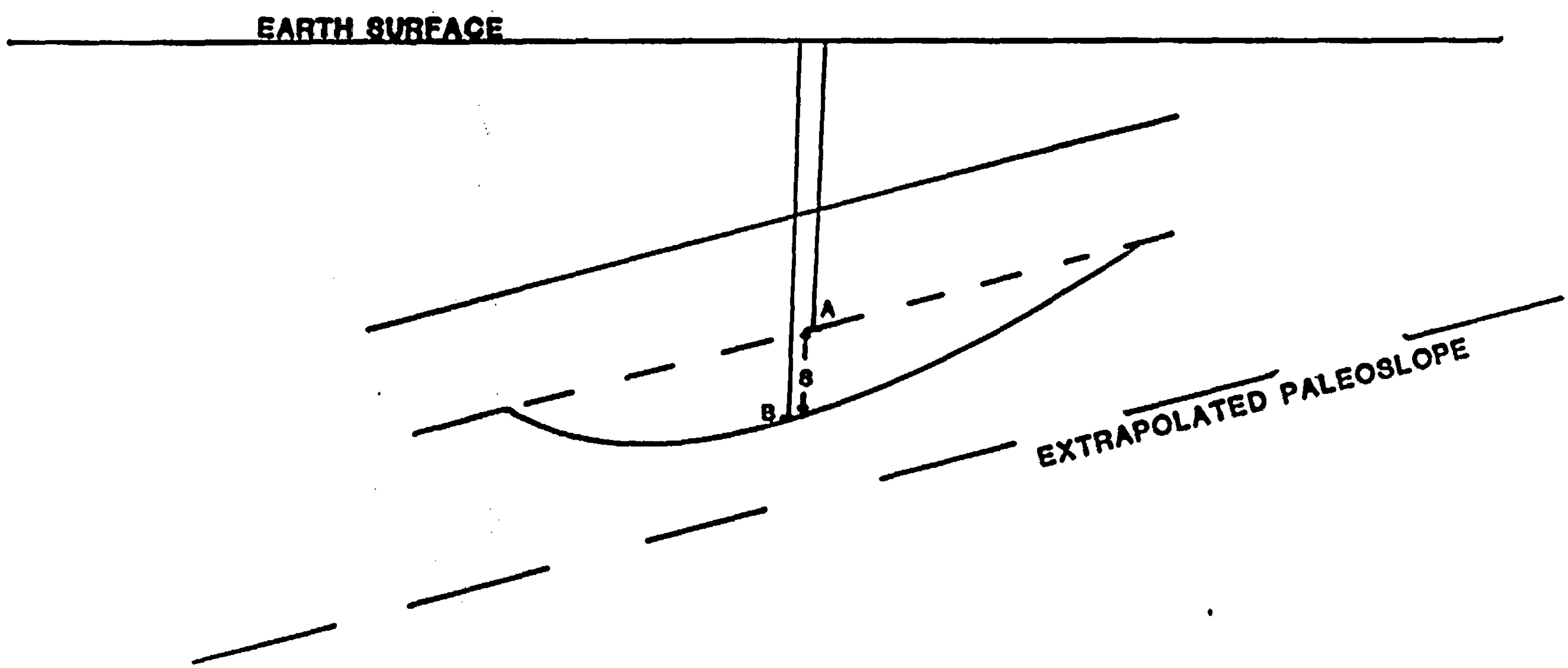


Figure 1 - Diagram showing how paleoslope is used to estimate subsidence and/or uplift.

A - extrapolated position of basalt bottom based on extrapolated paleoslope
B - actual position of basalt bottom determined from drill holes
S - subsidence = A - B, calculated from paleoslope method

near the reference point of the extrapolated paleoslope were compared to the thicknesses of flows measured at the crest of anticlines and troughs of synclines.

2) After calculating a combined uplift and subsidence rate for the Miocene, the present observed structural relief relative to the extrapolated paleoslope is used to determine the amount of relief that has occurred by uplift and subsidence. Using the proportions that have been uplifted and subsided, the combined uplift and subsidence rate for the Miocene is then divided using these same proportions.

Listed below are several assumptions involved in the application of these methods. Comments concerning the deficiencies inherent in these assumptions follow the assumptions.

1) The measured thickness at the extrapolated paleoslope is the true thickness that would have occurred in the area if uplift or subsidence had not occurred.

The "true thickness" is determined by an extrapolation of the paleoslope to the borehole. This method does not take into account structural control of the extrapolated paleoslope's elevation at the measuring point. Also, the location of measurement directly affects the subsidence or uplift values because the thickness of the basalt flows varies laterally along a slope.

2) Subsidence and uplift occurred at the same time and the relative proportions of each remained constant.

The validity of this assumption is certainly not known and probably not true. Because observed strain is concentrated in anticlines, it is suspected that deformation has been associated with uplift and less with subsidence. The constancy of the relative proportions of each is very difficult to ascertain. Also, because the regional tectonic picture is so poorly understood, the validity of these assumptions are difficult to assess because very little data can be collected for flow thicknesses near the extrapolated intersection of the paleoslope.

3) The regional paleoslope is assumed to be a reference point.

The regional paleoslope is not necessarily a reliable reference point. Subsidence or uplift of the paleoslope has been associated with the emplacement of the Idaho batholith which introduces error into the measurements made by Reidel, et.al. (1983). That is, if the paleoslope is uplifting, subsidence values for the Pasco Basin area will be too large and calculated uplift will be too small.

Figure 5-5 (p.5-9, Reidel et al., 1983) displays the rate of combined uplift and subsidence versus time for the Saddle Mountains and Rattlesnake Mountain from Grande Ronde time to the present. The present relief is determined from borehole DC-14 which is 5 miles away from the axis of the Wahluke syncline. Therefore, actual structural relief at the axis is probably greater between the Wahluke syncline axis and Saddle Mountain structure than what Reidel et al. calculate. Again, in Figure 5-

5, because DB-13 and DC-12 are 3 miles from the Cold Creek syncline axis, structural relief at the axis will be greater than what Reidel et al. calculate.

Movement is not continuous as Reidel et al. (1983) attempt to show but rather it is more episodic. Conceivably, movement could have ceased from time = 10 m.y. B.P. to time = 5 m.y. B.P., followed by a much faster rate-of-deformation (slope of line) to the present structural relief.

The greatest uplift rate is observed at Rattlesnake Mountain, that is, 34 m/m.y. The adjacent Cold Creek syncline subsidence was calculated to be <29 m/m.y. (p.5-11, par. 2). These dissimilar uplift/subsidence rates suggest different deformation processes are involved in the formation of these structures; this implies a tectonic discontinuity may exist between the two areas.

Reidel et al. (1983) admit that the uncertainty in the methods used to calculate uplift/subsidence, the nature of the base of the basalt, and anomalous areas such as Rattlesnake Mountain suggest determination of rates of uplift/subsidence for the Grande Ronde' time period is more complex than indicated by "this simple treatment".

## II. Horizontal Deformation Rates.

Associated with the uplift/subsidence calculations, Reidel et al. (1983) attempt to quantify crustal shortening rates. Price (1982) determined that crustal shortening measured in Umtanum ridge was accomplished by 1) reverse displacement along the Umtanum thrust, and 2) folding of the basalt flows. Price calculates a total of 965 m of shortening.

Reidel et al. (1983) use faulting on Umtanum Ridge (page 5-13, Reidel et al, 1983) to calculate a time frame for the crustal shortening.

"...at Umtanum Ridge, the youngest unit present, which is also deformed in the fault zone (Price, 1982) is the Priest Rapids flow (13.5 m.y. BP). Yet farther east along the same structure at Gable Mountain gravels probably $<$13000 yr. old are faulted (PSPL, 1982). If it is assumed that the 965 m of shortening took place over the length of time from Priest Rapids time to present (13.6 m.y. BP) at an approximately constant rate, then the rate of shortening would be 72 m/my"

Reidel et al.'s (1983) assumption regarding the length of time over which deformation occurred is incorrect. They assume that the 965 m of shortening occurred over a 13.6 m.y. period. Because the 13,000 year old gravels are faulted, then, by the Law of Cross-Cutting Relationships (AGI, 1976), faulting must have occurred during or after deposition of the gravels. Even though the gravels are not present at Umtanum ridge, one cannot assume faulting occurred during Priest Rapids time. Though the Priest Rapids member is the youngest layer faulted, faulting did not necessarily began when the Priest Rapids member formed, 13.6 m.y. ago. Faulting could have occurred at any time after the Priest Rapids formed. The deformation rate obtained from the previous assumption (72 m/m.y.), is a minimum estimate and highly speculative.

Additionally, Reidel et al. (1983) admit that data from other structures are necessary before this shortening rate can be considered to be representative of all folds.

Furthermore, faulting may have occurred episodically perhaps due to "stick-slip" mechanisms. Episodic deformation involves faster deformation rates and would affect the RRL with respect to DOE guidelines.

The evidence used by Reidel et al. (1983) to support low continuous deformation rates is problematic. The following presents the evidence and comments concerning its validity.

1) Thinning onto ridges and continued deposition and accumulation of sediments in those areas that are structurally below the extrapolated position of the regional paleoslope indicates deformation was occurring contemporaneously with deposition of sediments.

Extrapolated positions of the regional paleoslope are gross approximations that do not take into account subsurface structures (faulting) that may be present. Conversely, the regional paleoslope could be associated with uplifting due to the Idaho batholith thereby introducing errors into uplift and subsidence measured. Reidel et al.(1983) do not explain their extrapolation technique. Is it a linear continuation of the average regional paleoslope into the Pasco Basin area?

2) Cumulative deformation observed in the sediments indicates a long continuous period of deformation and low strain rates.

Cumulative deformation history in sediments is difficult to retrace. For instance, the uplift and subsidence currently observed can be the result of strain deformations not evenly distributed in time, as in the case of an episodic occurrence of large strains in a short time followed by much smaller strains over longer periods. This fact will certainly contradict the assumption of long continuous periods of deformation at small strain rates. To eliminate this contradiction, Reidel et al.'s conclusions may be interpreted in such a way that the strain rate is averaged over a time interval of 13.6 m.y.. If large episodic deformations do exist, as neglected by Reidel et al. (1983), then the deformation rates computed over a 1000 year interval can be much larger than what is allowable at the repository during its critical life time.

Also, since second order fold structures are observed in the Yakima fold belt, one may either assume continuous deformation (cumulative strain) or two phases of folding. The origin of second order structures must be understood to validate assumption #2.

Reidel et al. (1983) interpret greater dips of older sediments on the flanks of anticlines to mean that deformation was continuous throughout the deposition of the Ringold sediments and these older sediments were deformed more. Compaction and/or other varying sedimentary processes during diagenesis may account for the variation in dip of the underlying sediments.

3) Rates of uplift and subsidence extrapolated from the Miocene to the present can account for the present structural relief.

To test the validity of extrapolating uplift and subsidence rates to the present, Reidel et al. (figure 5-10, 1983) construct a residual top of basalt map for the Cold Creek syncline. This was calculated by subtracting the theoretical top of basalt (determined from extrapolation of calculated Miocene deformation rates to the present) from the observed top of basalt. This map shows several large (<300 m) anomalies between the two top of basalt values at Yakima Ridge, Gable Mountain and Gable Butte adjacent to the repository. Reidel et al. attribute these anomalies to a lack of data on ridges. However, the residual top of basalt map shows negative anomalies of <100 m throughout much of the Cold Creek syncline where more data is available. This makes extrapolation of uplift/subsidence rates quite suspect and reduces the credibility of extrapolating Miocene deformation rates to the present. Reidel et.al. attribute anomalies in the Cold Creek syncline to be within the margin of error of the technique. But the subsidence rates could also be in error.

4) The results of trilateration measurements (Savage, et.el. 1981: Ch. 6 of Caggiano and Duncan, 1983).

The conclusion regarding trilateration measurements drawn by Reidel et al. (1983) is contrary to conclusions of Rohay and Davis (1983) who determined that trilateration measurements revealed

> "...a shortening of 0.8 mm/yr. in an east-west direction, and a shortening of 0.4 mm/yr. in a north-south direction... This is an order of magnitude greater than estimated from geological or seismological data over comparable distances. The east-west shortening of distances is inconsistent with the geologic and seismologic data in the vicinity of the Pasco Basin."
>
> (p.6-29, Rohay and Davis, 1983).

## III Contemporary Deformation

Rohay and Davis (ch.6) attempt to quantify contemporary deformation in the Pasco Basin area. Contemporary deformation is determined from geodetic and earthquake seismologic data.

Earthquake epicentral data for the Pasco Basin and Columbia Plateau is determined from a seismic network constructed in 1969 by the USGS and later maintained by the University of Washington, Seattle, Washington. The network has had a station spacing of 25 km in the Hanford area. With this spacing, the accuracy in determining earthquake epicentral location accuracy is estimated to be 1 to 2 km, but determination of hypocentral depths may be in error by 2 to 4 km.

Earthquake swarms are the predominant characteristic of the Columbia Plateau seismicity. These earthquake sequences typically last a few days to several months. Earthquake swarms may contain up to 100 locatable earthquakes of (Richter) magnitude 1.0 to 3.5, but most are smaller than magnitude 2.0.

Rohay and Davis (1983) fail to address the anomalously straight north-south stretch of the Columbia River in the Pasco Basin at the eastern edge of the Hanford Reservation. The southward bend in structures (Wahluke syncline, Cold Creek syncline, Saddle Mountains) plus the southward bend of earthquake swarm patterns coincide with the southward bend of the Columbia River and suggests structural control of the Columbia River. Perhaps this is due to large-scale drag folding associated with the right-lateral Cle Elum-Wallula zone of deformation. Rohay and Davis argue against any alignment south of the Saddle Mountains; however, if one extends a line on the southward trend in the earthquake swarm pattern of the Saddle Mountains structure, this line would intersect Wooded Island (on the Columbia River), where "some of the most intense earthquake swarms in terms of numbers have occurred" (p.6-7,par.5, Caggiano and Duncan, 1983). An east-west linear trend of epicenters 5 km long is located at Wooded Island. This is consistent with right lateral slip of the Cle Elum- Wallula zone of deformation.

There is an apparent alignment of smaller earthquakes along the Saddle Mountains structure.

"The swarm earthquakes are concentrated north of the Saddle Mountains structure between Saddle Gap and the Columbia River at Sentinel Gap. This swarm activity gradually shifts to the south of the Saddle Mountains structure toward its eastern end. This shift in the location of seismic activity coincides with the approximate location of a slight bend in the axial trace of the anticline. Swarms south of the Saddle Mountains are separated by aseismic areas, so that no preferred alignment of these swarm areas is apparent...".

Deep earthquake activity has occurred near the Cle Elum-Wallula zone of deformation with two recent earthquakes in the Horse Heaven Hills structure having magnitude greater than 3.5 (3.8-1975 and 3.6-1979). Rohay and Davis (1983) note that there is no apparent concentration of deep seismicity along the Rattlesnake Hills structure. However, there is an apparent concentration of activity associated with the Saddle Mountains and Wooded Island (Columbia River) that is consistent with right lateral slip along the Cle-Elum Wallula zone of deformation.

Why isn't the Cle Elum earthquake of 2-18-81 with magnitude 4.2 (Table 6-2, p.6-10, 1983) discussed in conjunction with movement along the Rattlesnake alignment? Is there movement/activity along the Rattlesnake aligment that could be correlated with Pasco Basin tectonics? These questions must be resolved to adequately assess the tectonic stability of the RRL.

Focal mechanisms indicate the Pasco Basin basalt flows are responding to a nearly horizontal principal compression oriented north-south. Minimum compression is nearly vertical so that thrust or reverse faulting on east-west striking planes is indicated. This high compressive stress is continuous with depth (p.6-12, Caggiano and Duncan, 1983).

The stress field's orientation is subject to question. Anomalous strike-slip faulting has occurred recently (1936, 1979) on the western border of the Columbia Plateau and in the Walla Walla area (p.6-14, par.2, Caggiano and Duncan, 1983). Rohay and Davis (1983) note that "...there is sufficient variation in the focal mechanisms of small swarm earthquakes to indicate that they occur on a variety of fault orientations, which suggests some inhomogeneity in the stress field.."

Since the basalts are highly fractured, deformation and slip could be occurring on a series of discrete fracture systems which would respond differently to the same stress field and produce a variation in the resulting focal mechanisms. Also, "...the predominance of north-south compression and vertical tension supports a conclusion that most of the seismic deformation in swarms occur as thrust and reverse faulting on a number of very small east-west oriented planes, rather than a single, large fault plane." (p.6-14, par.4). When building the repository, in situ stress release will similarly occur making shaft and repository construction difficult.

Additionally, Rohay and Davis (1983) make several confusing remarks regarding strike-slip faulting (p.6-14, par. 5)

> "...right lateral strike-slip faulting has been presumed to occur on the Rattlesnake alignment in the central Columbia Plateau but earthquake hypocenters and focal mechanisms do not support this assumption..."

Yet the very next sentence states that

"...the composite focal mechanisms for deep events in proximity to this structure indicate roughly equal parts of strike slip and thrust or reverse movement..."

These two sentences seem contradictory. On the one hand, focal mechanisms do not seem to support strike slip faulting on the Rattlesnake alignment, and on the other hand focal mechanisms do seem to support strike slip faulting. What is BWIP's/Rohay and Davis's position regarding strike slip faulting? Other workers seem to agree that strike slip faulting has occurred on the Rattlesnake alignment (e.g., Myers, et al., 1979).

IV. Recurrence Relationships

To assess the present seismic character near the RRL, Rohay and Davis (1983) examined the recurrence relationships. This is done by determining the b-value (the slope of the line formed on a plot of magnitude versus total number of events above that magnitude). The b-value is normally 1.0, which indicates ten times more earthquakes of a given magnitude occur than earthquakes one magnitude unit larger. The b-values $\leq$ 1.0 indicate a greater proportion of larger earthquakes compared to smaller earthquakes; b $>$ 1.0 indicates a larger proportion of smaller earthquakes.

The b-values for the Columbia Plateau are 1.15 for shallow ($<$6 km) and 0.8 for deep ($>$6 km) earthquakes. This difference supports the concept of decoupling on a surface proposed to be the basalt-sedimentary rock interface. Additional evidence for decoupling includes focal mechanism solutions which indicate the rocks respond to the same stress regime but the mechanics of deformation may be different at depth (p.6-115, par.6, Caggiano and Duncan, 1983). However, if a sedimentary sequence exists at a depth of 3 km as indicated by magnetotelluric studies (ch. 4), large errors are introduced in the interpreted depth distribution of the earthquakes based on the present location model (p.6-17, par.1), thereby invalidating the observed difference in b-values.

**V. Deformation Slip Measurements**

Another method used by Rohay and Davis (1983) to estimate deformation rates utilizes two relationships which translate the observed frequency and size distribution of earthquakes into deformation slip:

$$Mo = u\ D\ A \qquad (1)$$

where

Mo = seismic moment of an earthquake
A = area of the rupturing fault
D = average displacement of the fault
u = the rigidity of the rock - taken to be $3 \times 10^{11}$ dyne/$cm^2$ (Lee and Stewart, 1981).

$$\log Mo = 16 + 1.5\ Ml \qquad (2)$$

where Ml = local (Richter) magnitude

The validity of the displacement estimates using these relationships depends on the following conditions:

1) Accurate magnitude measurement and the stability of the earthquake frequency with time.
2) Unbiased mean estimate of Ml, hence Mo, using a sufficiently large historical database. Rohay and Davis (1983) only used data from 1969 to 1979. The deformation rates estimated are most dependent on the largest earthquakes in the data sample: relatively long time periods provide better estimates. However, this

would require use of historical data which is not reliable.

In addition, the following assumptions were made.

1) Rohay and Davis (1983) considered decoupling exists between two volumes of rock when estimating deformation rates in basalt and the rocks below basalts. Because all of the recorded seismic activity greater than magnitude 3.0 occurs between the Frenchman Hills and Umtanum Ridge-Gable Mountain anticlines, deformation slip was assumed to occur on the Saddle Mountains anticlinal structure.

2) The boundaries of the study area (46-47 degrees north latitude, 118.75 to 120 degrees west longtitude) exclude the Yakima Ridge and Horse Heaven Hills seismicity. The proximity of these structural provinces to the RRL dictates that this seismic data should be included in the data set.

3) Rohay and Davis (1983) obtain an average seismic moment (Ml) of 3.79. They assume a fault plane area defined by 5 km height (45 angle to 3 km depth) and length 50-100 km This produces a value for deformation slip of D = 0.03 mm/yr (A = 500 $km^2$) to D = 0.06 mm/yr. (A = 250 $km^2$). If, however, deformation slip is assumed to occur on a fault with A = 10 $km^2$ (1 km X 10 km), then the deformation slip (D) = 1.5 mm/yr. Obviously this analysis is subject to the fault model chosen. Choice of a fault model that has a deformation slip in

agreement with other slip calculations (e.g., geologic) neither validates nor supports the choice of fault model chosen or the slip rate computed.

Also, if the 1936 Milton-Freewater event is considered, then "...average rate of seismic deformation in the larger region is 10 times higher than previously estimated from post-1969 instrumental data..." (p.6-20, par.3, Caggiano and Duncan, 1983). Although the Milton-Freewater event is "... inconsistent with the style of deformation in Columbia Plateau..."(p.6-20, par. 3) its exclusion from the database is questionable.

In support of the decoupling theory, deformation per unit volume is 10 times higher in the basalts than in the rocks below the basalts. Rohay and Davis (1983) suggest two reasons why deformation per unit volume is 10 times higher in the basalts than in rocks below the basalt.

1) The basalts may be more brittle. Because of increased pressure and temperature at depth, one would expect more aseismic activity and deformation at depth.
2) The basalts may be mechanically decoupled from the rocks underneath it.

In summary, several limitations exist in Rohay and Davis' estimates of 'D', the average displacement of the fault.

1) Seismic moment data is approximately accurate by a factor of 5.
2) Moments are based on seismic activity over a 10 year

period only. This is certainly not a representative data base from which to make estimates of deformation rates for the time period, Miocene to present.

3) Exclusion of nearby earthquake data (e.g., the Milton-Freewater event) may not be correct.

## VI Geodetic Surveys

Final measurement of contemporary deformation involved geodetic surveys. Rohay and Davis (1983) present geodetic data in two data sets, pre-1970 and post-1972 surveys. Pre-1970 data shows subsidence of 1 mm/yr.-2mm/yr. Post-1972 surveys suggest a minimum horizontal strain accumulation that barely exceeds the limitation of the technique.

The geodetic post-1970 strain rates are

$$E1 = -0.016 \pm 0.018 \text{ mm/km N } 5^{\circ} \text{ E}$$
$$E2 = -0.041 \pm 0.018 \text{ mm/km N } 85^{\circ} \text{ E}$$

E1 and E2 are the largest and smallest principal strains, with negative values of strain rates denoting compression. This east-west contraction is contrary to the regional focal mechanism solutions by Savage, et. al. (1981) who noted that geodetic data agree with the Milton-Freewater earthquakes.

Rohay and Davis (1983) note that geomorphic features associated with faulting have been observed along the inferred location of the Wallula fault system and the Rattlesnake Hills anticline. Three triangular networks independent of one another were established along the inferred trace of the Wallula fault system. If deformation is localized along particular structures, long-term average rates determined for the entire basin by averaging local effects over a larger volume would be an unrealistic model of deformation.

Rohay and Davis (1983) admit that

"the geodetic data indicate a shortening of 0.8 mm/yr. in an east-west direction, and shortening of 0.4 mm/yr. in a north-south direction for the average line length of the survey (20 km). This is an order of magnitude greater than estimated from geological or seismological data over comparable distances. The east-west shortening of distances is inconsistent with the geologic and seismologic data in the vicinity of the Pasco Basin" (p.6-29,par.5).

## VII Conclusions

The paleoslope-Columbia basalt relationship must be understood in more detail to determine the validity of calculated deformation rates based on the paleoslope reference.

If coupling exist between the basalts and the sub-basalt rocks, extrapolation of structures underneath the Columbia Plateau is justified. If decoupling seems evident, then deformation in the Columbia Plateau cannot be easily explained by regional tectonics. Deformation in a decoupled Plateau is influenced predominantly by the rheological properties of the basalt (i.e., brittle deformation, shallow (¼6 km) structural extent). BWIP must attempt more work to determine if decoupling is present at Hanford, as their preliminary work suggests.

Future work should include a re-evaluation of the data base used to calculate deformation slip. The exclusion of certain earthquakes (e.g., Milton-Freewater event, Horse Heaven Hills seismicity) must be examined to determine if such exclusion is justified.

BWIP's progress to date determining the Tectonic Stability of the Hanford area is highly preliminary. Further work will require detailed examination of regional tectonics on the RRL basalt layers. The presence of offsets in drillholes DB-10 (vertical throw = 160 feet), DC-8 (throw undetermined), DC-14 ( throw = 4 inches), and core disking are directly attributable to the past and present tectonic stress regime (Myers, et al., 1979). The regional tectonic model must account for the smaller scale structures observed near the RRL.

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