Lawrence Livermore National Laboratory

NUCLEAR SYSTEMS SAFETY PROGRAM

WM DOCKET CONTROL

September 28, 1983
EG-83-084/1095u

A0294

WM-10,11,16

PDR
LPDR

Ms. Martha W. Pendleton
Project Manager, MS 623ss
High Level Waste Tech. Development Branch
Division of Waste Management
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

SUBJECT: LLNL Evaluation Report on RHO-BW-ST-19-P

REFERENCE: NRC FIN A0294, "Technical Assistance in Seismo-Tectonic Impacts in Repositories"

Dear Ms. Pendleton:

This is to transmit the subject Evaluation Report on "Preliminary Interpretation of the Tectonic Stability of the Reference Repository Location, Cold Creek Syncline, Hanford Site," RHO-BW-ST-19-P, dated March 1983 (referred to below as ST-19). ST-19 is a key document for the BWIP site. Our technical review and evaluation of ST-19 was identified by the NRC/PM (in concurrence with the LLNL project manager) as an action item at the August 17-18 meeting.

Our review and technical evaluation of ST-19 is somewhat lengthy, but necessary. The ST-19 compiles and characterizes data which were available before May 1982 about the tectonic stability of the BWIP site. The collection and integration of these data is difficult; ST-19 is a useful document reviewing most of the vital information about the area. We feel that ST-19 is more comprehensive than earlier ones for the Reference Repository Location Site, where the database is extensive. However, the ST-19 is less definitive and less complete for some of the regional relationships which have not received as much attention or study by the Rockwell-Hanford Operations group. We feel that focus on selected regional and site specific data is needed to resolve issues that are relevant to the site.

8409120027 830928
PDR WMRES EXILLL
A-0294 PDR

In closing, I would like to acknowledge Don O. Emerson, H. Larry McKague, D. Burt Slemmons, and Bob Whitney for their timely contributions in this task.

If you have any questions, please let us know.

Sincerely yours,

D. H. Chung
Project Manager

DHC:tp

cc:

AT NRC

S. Copland, NMSS/DWM
P. S. Justus, NMSS/DWM
H. J. Miller, NMSS/DWM
P. T. Prestholt, NMSS/DWM
R. J. Wright, NMSS/DWM

AT LLNL

D. L. Bernreuter, L-95
D. O. Emerson, L-202
H. L. McKague, L-224
D. B. Slemmons, UN-Reno

Review Comments on

Preliminary Interpretation of the Tectonic Stability of the Reference Repository Location, Cold Creek Syncline, Hanford Site

RHO-BW-ST-19P - March, 1983

GENERAL COMMENTS

This report compiles and characterizes data about the tectonic stability of the BWIP site which was available before May, 1982 (in spite of the March, 1983 report date). The collection and integration of these data is difficult and this document is a useful review of most of the vital information about the area. This report is more comprehensive than earlier ones for the Reference Repository Location (RRL) Site, where the database is extensive. However, it is less definitive and less complete for some of the regional relationships which have not received as much attention or study by Rockwell Hanford Operations (RHO). Focus on selected regional and site spcific data is needed to resolve issues that are relevant to the Site.

SPECIFIC COMMENTS

The major emphasis of this and preceding RHO studies and reports has been on the variability in thickness of the basalts and their intervening sedimentary members as a function of source areas, Pasco Basin development, and the timing relative to major anticlinal folds of the Columbia Plateau. The evaluations from selected, scattered boreholes and surface expression in the Saddle Mountain, Gable Mountain and Umtanum Ridge areas have been the focus of general as well as detailed jointing, petrochemical, and structural studies. These and associated studies have led to a better understanding of jointing features of the Columbia Plateau and their terminology. In spite of these studies, however, there are unexpected variations in thickness, fracture pattern and hydrologic character of the basalt at the proposed repository area (see USGS, May 6, 1983, comments in their review report). Our review of compilations of borehole thickness show relations that may not fully support the position presented in the RHO report. Detailed questions and comments follow, perhaps more detailed explantions or compilations will explain some of the geologic relations.

Many of the figures present data that are for the Study Area only (Figures 3-9 through 5-10). These do not analyze the relations for the nearest major geologic structure, the Cle Elum-Wallula, or RAW structure that both affects the southwestern edge of the Study Area and is much closer to the Reference Repository Location than most of the Ratlesnake Ridge area. The much thicker sections shown beneath Rattlesnake Ridge do not agree with the basic concepts that are presented for the Cold Creek Syncline or anticlinal structures to the north.

On Regional Relationship:

The geologic interpretations need to include more regional data along the Cle Elem-Wallula structure. Much of this data has been collected by Washington Public Power Supply System and Puget Sound Power and Light and their consultants, or by the NRC. These data need to be evaluated and integrated with RHO compilations that emphasize areas to the north.

Tectonic Setting -- The rate of tectonic evolution of this region is low, as is shown especially by many RHO reports and investigations. The relatively low rates of activity calculated by RHO and shown for the Cold Creek Syncline area are based mainly on the character of deposits at the Site, and at Umtanum and Saddle Mountain anticlines to the north. The relationship to a major, and even nearer structure along the Cle Elum-Wallula or RAW trend, the Rattlesnake Mountain structure, requires further investigation. The very high hypsometric values for formations within Rattlesnake Mountain relative to the Site suggest major differences in timing of structural deformation, geographic focus in deformational activity, southwestward sloping of basaltic deposition relative to Pasco Basin, and penecontemporaneous relations that are used within this document. These need to be more fully discussed and related to the Site.

The collection of specific data on the nature of RAW, its parameters, timing and tectonic character is needed to properly evaluate stability and seismic potential at the Reference Repository Location. The resolution of these issues on RAW are needed to provide more accurate data on the seismotectonic influence of RAW and to place appropriate error bands on the determinations that are made.

Seismotectonic Character -- The seismotectonic character of this region is explored in a variety of papers and by use of different models or assumptions. These studies include specific studies and regional seismic hazard and exposure studies for the Hanford area, which are tabulated, but are not evaluated by the RHO studies. The maximum design earthquakes are based on correlations that need to be evaluated for the Reference Repository Location. This is not done in this or other RHO reports. The maximum earthquakes for RAW, or parts of RAW, include estimates of Ms up to magnitude 6.5 to 7, and the structure is mapped to within about 10 km of the Site Area (see maps of Figures 4-3 to 4-6; note errors in scales). Campbell and Bentley (1981) and Slemmons (in USNRC, 1983) provisionally assign higher magnitude values to the Yakima fold belt, which extends westward from near Rattlesnake Mountain to the Cascade Range. The attenuation from sources to repository structures is not evaluated in this report.

Previous Recommendations — The LLNL recommendations 1 to 7, in our letter of April 27, 1983, have not been resolved in the RHO report. These recommendations will require further research by RHO and these and related issues should be evaluated in future studies.

SPECIFIC COMMENTS ON DOCUMENT

Executive Summary

As indicated, the interpretation of the available data is preliminary. Uncertainties will need to be addressed during the detailed site characterization. With this in mind, the Executive Summary is a brief status report of current thinking about the tectonic stability of the site.

Page v, Bullet 2: The suggested lack of hypocenter alignment with faults is somewhat misleading and stronger than the seismological data indicate. Many small earthquakes of this area show a crude alignment along or near anticlinal-fault structures (see Figure 6-3). The low regional seismicity, or the possibility of low to horizontal dips of faults, or the long recurrence intervals may provide the weak correlation between earthquake epicenters and faults or folds. The use of stereographic plots similar to that used by Reasenberg and Ellsworth (1982) might emphasize or clarify the weak correlations shown by present data.

Page v, Bullet 5: Lack of seismicity is common before many large earthquakes, but may be well expressed during aftershock or creeping phases of activity. Thus, the apparent lack of historical activity may not indicate absence of tectonic activity for this zone.

Chapter 1. Rational and Approach for a Tectonic Stability Assessment of the Reference Repository Location

This well written chapter selects (but not exclusively) seven criteria for tectonic stability. In addition, it selects a period of 10,000 years into the future for stress and strain projections and 15 million years from the past for data to be used as input to the tectonic model.

Page 1-5, Para. 3: The goal of establishing a conceptual tectonic model for the BWIP Site is admirable, but unless this is definitive, and other models can systematically be rejected, the use of multiple models (as indicated in Chapter 7) may be required for current analyses.

Page 1-7, Para. 1: This might be more conservative if it indicated that geologic processes may not continue at uniform rates and that catastrophic events need to be considered.

Chapter 2. Geologic Summary of the Columbia Plateau

This chapter sets a scene but leaves so much out that it is not clear if it really helps. The Introduction basically suggests that you read the cited references. The Pasco Basin summary lacks any detail, or even an illustration, on either the cross structures that define the RRL or the interflows that are candidate horizons.

Page 2-3, Fig. 2-2: This somewhat dated figure provides a misleading impression of plate movement. The north arrow is incorrect and the North American Plate is not fixed. Vectorial resolution of the movements would be more useful for gaining the big picture.

Page 2-4, Fig. 2-3: This figure is not consistent with Figure 5-2 (page 5-4) for interbeds and/or basalt members. Is there an issue in the differences in the stratigraphy shown in the two sections?

Page 2-5, Para. 1: Should the term "Tertiary" be replaced by "Cenozoic"? The discussions in other parts of the text suggest that the processes which caused the Pasco Basin were operative in the Pleistocene and probably during the Holocene.

Page 2-5, Para. 2: Do the possible features of northwest trend suggest lineaments or major structures, active or otherwise, that affect stability and groundwater circulation at the Site? Expand, name or delineate, and characterize the nature of these northeast- or northwest- trending structures. Does this conflict, or possibly conflict, with the statement on page 2-5 that "The reference repository location is one of these masses of intact rock."?

Page 2-6, Fig. 2-4:

Section A-A' -- Why was the line bent to the east over the Yakima Ridge structure where borehole data should be available on the line (i.e., borehole RRL-2 of Figure A-8 in draft SCA)? This bend tends to minimize, in the cross-section, the visual impact of folding of Yakima Ridge.

How does a relative gravity high beneath the Pasco Basin within an area of low gravity accompany the thin crust interpretation?

Page 2-11, Para. 1: The low historical seismicity appears to be related to the relatively low tectonic activity, but there is a low historical level along many active faults and in tectonically active zones. Many Columbia Plateau earthquakes tend to be on or near the Yakima fold belt and other anticlines or their associated faults. Correlations assume high angle faults, but the dispersal of activity could be near neohorizontal faults. The largest earthquake, the Milton-Freewater earthquake in 1936 of about Ms = 5.7 had an epicenter near the junction of the Hite fault and the Cle Elum-Wallula (RAW) zone of deformation, and that zone passes within ten km of the proposed Site. This relationship should be noted here and discussed in the text and/or the appendices.

Pages 2-12 & 13, Fig. 2-8 & 9: The seismicity shown on these figures is different than on Figure 6-3. Why are these maps different in what they show?

Page 2-15, Para. 2: The normal faults are associated with reverse faults and scarps that are listed by NRC (1983, p. 2-37; Slemmons, in USNRC, 1983). These scarps may be associated with large Holocene earthquakes and suggest that part or all of the Yakima fold belt is tectonically active.

Page 2-20, Para. 2: The greater thickness of the Wanapum Basalt in the Rattlesnake Mountain area than at the Site suggests that this fold may not have been contemporaneous with the Saddle Mountain anticline. The data suggests a possible southwestward extension of the Pasco Basin at Wanapum time, and a more recent, post-Grande Ronde origin of this structure. Has this possibility been evaluated for the character, style and timing of deposition and deformation at Rattlesnake Mountain?

Page 2-21, Para. 1: Data and diagrams presented in text suggest that anticlinal folding cannot be demonstrated until after Saddle Mountain time. On what data is deformation in early Wanapum time based?

Page 2-21, Para. 3: Because strain rates are calculated on the assumption that the Yakima Fold Belt was developing penecontemporaneously with the Saddle Mountains, further proof is necessary or strain rates must be made more conservatively.

The thinning of the Selah interbed suggests deformation but is not conclusive of deformation. Interbeds are reported to be of variable thickness in synclines and undeformed areas. What other interbeds change in thickness at the structure and what data shows this?

Plate 2-1 & 2: It would help if these plates had latitude and longitude and/or township and range information on them. It would also be useful to have the Reference Repository Location marked on all maps as it is on Plate 2-2.

Chapter 3. Regional Geologic Setting of the Columbia Plateau

A brief background on the difficult problem of determining, from a regional setting, what types of geologic structures may exist below the basalt. As indicated (page 3-1, 1st paragraph), "The potential for displacement on such possible stuctures beneath the basalt needs to be assessed." Many questions are unanswered, such as the reason the east-west trend of folds and faults in the Yakima Fold Belt (so important to the Site) are not obvious in the major structures surrounding the plateau (page 3-5, 3rd paragraph). The conclusion (page 3-12) is that the determination of the structures beneath the Pasco Basin will depend on the interpretation of geophysical data.

Chapter 4. Pre-Columbia River Basalt Group Stratigraphy and Structure in the Central Pasco Basin
(Including) Appendix A - Geophysical Methodology and Observations

Any attempt to explain the structure in the Pasco Basin by an overlay of geophysical data would be difficult. The lack of borehole control for geophysical interpretations of deep structures leaves room for many different models that could all fit the same data. Although BWIP has proceeded to the modeling step (#4 of page 4-2), it is still necessary to evaluate the need for new data and interpretations to determine the most realistic structural models.

Pages 4-5 to 9, Figs. 4-3 to 7: The scales are about 1/2 actual.

Page 4-9, Fig. 4-7: This map is misleading in that; 1) positive and negative anomalies (isopach or hypsometric) are not differentiated, 2) the two western anomalies are both of the same nature, yet have two gradients shown and the two eastern anomalies are opposite in nature, but only show one gradient, and 3) some anomalies are not shown.

Page 4-10, Table 4-1, Anomaly #1: Quote, "Corresponds with Rattlesnake Hills structure." This is true but the anomaly is opposite to present topography, therefore it corresponds geographically with Rattlesnake Hills structure but not from a hypsometric or isopachic standpoint.

Page 4-11, Bullet 3: The word conservative should be defined or deleted.

Page 4-14, Para. 4: In the definition of Type II, it should be stated that deep and shallow structures are not only "not vertically continuous", but in laces (e.g., Rattlesnake Hills) actually oppose each other.

Page 4-16, Para. 3: It is true that some of the Yakima folds may be exemplified by Umtanum Ridge, but certainly other types are known, e.g., Rattlesnake Hills. This needs a detailed discussion.

Page 4-18, Bullet 1: How can pre-basalt structure and stratigraphy influence Yakima folds when opposite relationships can be demonstrated for folds, i.e., in Gable Mountains Layer 3 is high, and in southeast Rattlesnake Hills Layer 3 is low?

Chapter 5. Constraints on Tectonic Models as provided from Strain Rates (Including) Appendix B - Methodology for Computer Assisted Determination of Rates of Deformation

This integration of basalt extent and thickness with the concept of a constant regional paleoslope highlights the anomalous features in the Pasco Basin area. The analysis needs to be extended to the south and west of the Site to illustrate some of the limitations of these data.

Page 5-5, Para. 1: Table 1 is from measured section boreholes shown in Plates 111-5, 1 and 2 of RHO-BWI-ST-4. Because of the small vertical exageration the measurements are probably only correct to about 20 feet.

An interpretation of these data could be minor thinning of Wanapum basalt except in Rattlesnake Hills, minor thinning to thickening of the Ellensburg Formation interbed between the basalt formations except at Saddle Mountains where it is pinched out, and no discernable change in Saddle Mountains basalt (the youngest unit) except at Saddle Mountains, where it thins somewhat.

This certainly is not "consistent" thinning and in fact may show consistent thickening over some structures (e.g., 134 feet of thickening over Rattlesnake Hills).

Because of these data, strain rates calculated between the Cold Creek Syncline and the Rattlesnake Hills and Umtanum Ridge structures are probably in error. Should these rates be calculated from flow top or interbed top data from boreholes? What microstrain units are obtained from these?

Page 5-6, Fig. 5-3: Thrust faults are indicated on the legend, known on several anticlines, but are not shown on the map.

Page 5-7, Para 1: Quote, "Because the flows thin over ridges and less often pinch out on the flank, ..." This is not proven for all flows and data suggests (Figure 2-4, RSL- 1 borehole) that this may not be the case for some folds (e.g., Rattlesnake Mountain). Strain rates for elevations of basalt in Rattlesmake Mountain and Cold Creek Syncline need to be calculated using flow base elevations, which would negate the effect of subsidence at Rattlesnake Mountain in Miocene times. This may increase observed strain rate by 200%.

Page 5-7, Para. 3: Extrapolation of paleoslope into Pasco Basin may be in error if deformation at Rattlesnake Mountain was occurring in the Miocene. This may be indicated by isopach maps of Layer 2 and the top of Layer 3 (Figures 4-3 and 4-5).

Table 1.

Borehole Number	Thickness of Saddle Mtns. basalt flows (and interbeds of Ellensburg Formation)	Thickness of Wanapum basalt flows	Thickness of interbed of Ellensburg Formation between Saddle Mtns. and Wanapum flows	Structure on which borehole is located
DC-4/5	748'	1142'	118'	Cold Creek Syncline
DB-11	472'	not measured	157'	Cold Creek Syncline
DC-3	709'	1102'	157'	Cold Creek Syncline
DC-7/8	827'	1102'	79'	Cold Creek Syncline
DB-14	826'	not measured	118'	Yakima Ridge
RSH-1	591'	1260'	118'	Rattlesnake Hills
DC-6	669'	1023'	79"	Umtanum Ridge
DH-4	433'	1023'	-0-	Saddle Mtns.
(average)	657'	1126'		

Page 5-8, Fig. 5-4: This map only shows selected boreholes. Need a map and data from all available boreholes in and near Pasco Basin, or change the caption to read "Selected Borehole Location Map".

Page 5-14, Para. 4: Should include Rattlesnake Mountain as one of the prominent features in the area, even if the total anomaly is not shown, because what portions are shown indicates this area is the greatest in disagreement.

Page 5-14, Para 4: The data density for the top-of-basalt on the ridges, where it is exposed, should be better than in the syncline, where only borehole data exist. Why are the syncline top-of-basalt measurements thought to be better known?

Pages 5-15 to 17, Figs. 5-8 to 10: Expand the area to include Rattlesnake Mountain.

Page 5-18, Para. 2: Quote, "Several minor anomalies between the observed and theoretical top-of-basalt maps (figure 5-10) occur in Cold Creek Syncline." Examples shown are true but give anomalies of about +500 feet and -200 feet differences. If the Rattlesnake Mountain data were included, between DC-8 and the Mountain an anomaly in excess of +2000 feet may exist if the trend of contours toward the Mountain continues. There is now about 3000 feet of difference, this is not a minor anomaly.

Within the area chosen to plot, anomalies as great as 1000 feet exist, twice what is shown by the examples in the text (i.e., Yakima Ridge to Cold Creek Valley depression).

Page 5-19, Bullet 1: Not all Yakima folds were growing in Grande Ronde time. Uplift rate on folds did not decline in early Miocene for all folds. See text for discussion of Rattlesnake Mountain.

Page 5-19, Bullet 2: Not all growth concentrated on Early Miocene structures. See text for discussion of Rattlesnake Mountain.

Chapter 6. Contemporary Deformation in the Pasco Basin Area of the Central Columbia Plateau

This discussion does not evaluate the issue of whether or not the RAW, or Cle Elum-Wallula trend, is fault-controlled, and if so what fault types are present at depth and what are fault parameters and design earthquake values? The potential for "floating" or random earthquakes is not assessed. The proximity to the Yakima fold belt is not defined in a province map and the seismic potential, active structure(s) and design earthquake values are not estimated for effect on stability at the Site.

Page 6-8, Fig. 6-3: The caption on this figure does not indicate the period of instrumental recording.

Page 6-9, DEEP EARTHQUAKES: The presence of deeper earthquakes suggests that there is tectonic activity in this area. The activity is low, which is compatible with the geologic data. This low rate, with the long recurrence intervals shown by the geologic data indicate that the historical seismological events may have limited use for delineation of earthquake structures.

Page 6-12, FOCAL MECHANISMS: This section is a useful compilation, but scatter in the limited data (Table 6-2) shows anomalies or scatter in orientation of compression axes.

The possible right-oblique slip suggested in the last sentence of page 6-14 is also suggested is some of the models (see Slemmons, in USNRC, 1982).

Page 6-15, RECURRENCE RELATIONSHIPS: The recurrence interval relationships, shown by the small earthquakes used for this useful analysis, may or may not fit the data for larger earthquakes of this area.

Page 6-29, SUMMARY: The field fault and fold relationships along the Rattlesnake-Wallula alignment has not been assessed by RHO and definitive data to support the position suggested by the first paragraph has not been evaluated by both geologic and seismologic data. This is a critical geologic (and possibly seismologic) structure that bounds the southern edge of the Reference Repository Location. The lack of a complete evaluation precludes the possibility of making definitive judgments of the stability at the Site. This section has not been closely integrated with Chapter 7.

Chapter 7. A Review of Tectonic Models of the Columbia Plateau and Pasco Basin

This is an excellent review of current regional and local models and the main areas of agreement and disagreement. Major differences in models provide great variation in seismic exposure and future stability at the Site. The present major error bands will persist until basic tectonic-seismic issues are resolved.

Page 7-18, Para. 3: Avoiding the classification of thin- and thick-skinned tectonics does not preclude dismissal of the question of regional or at least large-scale local decollements, either between basalt flows or between the basalt and underlying rocks. A third bullet to address the question of decollements, whether shallow or deep, should be added. Models such as Bruhn (1981) shown in Figure 7-3 (bottom) and Price (1982) shown in Figure 7-4 (bottom) indicate decollement at a shallow depth (to a few thousand feet) may not only be present, but prevalent. Decollements below unthrust faulted anticlines help geometric relationships at shallow depths to avoid plastic deformation of brittle material (basalt) without significant geopressure. Caggiano states on page 8-1 (2cd paragraph) that some slip may occur along layer boundaries. If this slip extends outside of the fold, this is a decollement, and present data is insufficient to rule out this possibility. Disking of borehole cores in synclinal areas indicates sufficient horizontal stresses exist in flat lying strata to accomplish decollement, and hypocentral depth of earthquakes appears to decrease as a log function down fault plane dip on some faulted anticlines.

Chapter 8. A Preliminary Assessment of the Tectonic Stability of the Reference Repository Location

This short chapter indicates that several important questions about tectonic stability need additional study (pages 8-5 & 6). Without these studies, the degree of tectonic stability at the Site remains questionable.

Page 8-2, Para. 1: For strain rates (horizontal) of 0.02 to 0.04 mm/km/yr compression across a 60 km wide basin (e.g., the Pasco Basin), total compression is 1.2 to 2.4 mm/yr or 1 cm every 4 to 8 years, 1 m every 400 to 800 years. Possible recurrence, if all of the strain is elastic, and concentrated in one structure, of 2 m every 800 to 1600 years. On a thrust, 2 m of movement during one event is a very large displacement. How is this strain distributed in surface rocks, and is the movement brittle failure from stored elastic strain (as evidenced by disking in borehole cores) or plastic (which seems improbable without sufficient overburden giving high geopressure)?

Page 8-3, Para. 1: The text states that basement structures in Snively Basin correlate to surface structures, but that they do not correlate in other parts of the Yakima fold belt. Why, in Chapter 7, is Snively Basin used in the context of a "typical" basin in the Yakima fold belt?

Page 8-4, Para. 4: Price (1982) concludes that "... folding strain should be concentrated in areas of steeply dipping strata ..." yet borehole cores in horizontal strata show disking from in-situ strain. Does this mean more strain is present in the dipping strata? Where is the in- situ stress with respect to a Mohr's envelope of brittle fracture diagram for basalts?

Page 8-4, Para. 5: Strain is given at 1 mm/yr for the basin. On page 8-2, strain is given as 0.02 to 0.04 mm/km/yr. As the Pasco Basin is about 60 km north to south (direction of compression), this 0.02 to 0.04 mm/km/yr gives 1.2 to 2.4 mm/yr strain across the basin. Why do these figures vary from 1 to 2.4 mm/yr?

Page 8-5, Para. 1: Strain rates are compared to the central fault on Gable Mountain. All cross-sections do not show this mountain faulted, much less multiple faults as the word "central" implies. Displacement may be distributed across imbricate systems which splay from a single fault or decollement at depth. Does the strain rate increase if imbricate fault models are used? Can it be shown that strain is evenly distributed across the Yakima folds such that a low rate of deformation on one fold can be extrapolated across the Pasco Basin?

Page 8-5, Para. 3: Epicenters align on maps only on steeply dipping fault planes. Have cross-sections been used to determine alignment of hypocenters on faults with moderate, low, or no dip?

Page 8-6, Para. 3: "Tectonically stable" areas need a comparison with areas of better understood seismicity (e.g., the San Andreas, the system of strike-slip faults in southern California, northern Baja California, the Basin and Range, the Rocky Mountain front in Colorado, and Kansas).

Chapter 9. References

Of the 230 references cited, it is interesting that only 19 are prior to 1970. This attests to the vast amount of work that has gone on in this area in recent years.

REFERENCES

Bruhn, R. L., 1981, Preliminary analysis of deformation in part of the Yakima Fold Belt--south-central Washington: Report prepared for Washington Public Power Supply System, Richland, Washington, 27 p.

Campbell, N. P., and Bentley, R. D., 1981, Late Quaternary deformation of the Toppenish Ridge uplift in south-central Washington: Geology, v. 9, p. 519-524.

Lawrence Livermore National Laboratory, April 27, 1983, Summary Report on "Technical Assistance in Seismo-Tectonic Impacts in Repositories, BWIP Tectonic Workshop, April 12-15, 1983," Lawrence Livermore National Laboratory, Nuclear Systems Safety Program, cover letter and 7 pages.

Price, E. H., 1982, Structural geometry, strain distribution, and tectonic evolution of Umtanum Ridge at Priest Rapids, and a comparison with other selected localities within Yakima fold structure, south-central Washington: Ph. D. dissertation, Washington State University, Pullman, Washington; also RHO-BWI-SA-138, Rockwell Hanford Operations, Richland, Washington.

Reasenberg, P. and Ellsworth, W. L., 1982, Aftershocks of the Coyote Lake, California, Earthquake of August 6, 1979: A detailed study, J. Geophys. Res., 87, 10637-10655.

Rockwell International, March 1983, Preliminary Interpretation of the Tectonic Stability of the Reference Repository Location, Cold Creek Syncline, Hanford Site: Rockwell Hanford Operations, RHO-BW-ST-19P.

U.S. Geological Survey, May 6, 1983, Letter of review of the "Preliminary Interpretation of the Tectonic Stability of the Reference Repository Local, Cold Creek Syncline, Hanford Site,": U.S. Geological Survey '83 May 11 A11:45, Mail Stop 410, 6Op

U.S. Nuclear Regulatory Commission, March 1983, Draft Site Characterization Analysis of the Site Characterization Report for the Basalt Waste Isolation Project, Hanford, Washington: U.S. Nuclear Regulatory Commission, Main Report and Appendices A through D, NUREG-0960, Vols. 1 and 2.