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Evidence of Tectonic Stability Along the Middle Columbia River, Washington, in Quaternary Time

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EVIDENCE OF TECTONIC STABILITY ALONG THE MIDDLE COLUMBIA RIVER, WASHINGTON, IN QUATERNARY TIME

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ABSTRACT

Observations of outcrops and Pleistocene-age surfaces along the Columbia River, between Priest Rapids Dam and Richland, Washington, provide evidence for recent tectonic stability that may be significant to planning of earthquake-sensitive engineered structures in the vicinity. Apparent continuity of layering in the Yakima Basalt (Miocene), Ringold Formation (Pliocene), and calcrete capping much of the Ringold Formation (more than 100,000 yrs old), and the absence of appreciable deformation of several large, smooth, late Pleistocene surfaces indicate that there has been little or no deformation along much of this part of the Columbia River since these rocks and surfaces were formed.

INTRODUCTION

The area studied in preparation of this report is the valley of the Columbia River in south-central Washington, between the city of Richland, on the south, and Priest Rapids Dam, on the northwest (fig. 1). It includes nearly all of the eastern and northern parts of the Hanford Site of the U.S. Department of Energy (fig. 1; designated by former name "Hanford Works," on base map of pl. 1). It is a region of arid climate and sparse vegetation.

Previous and Present Studies

Evidence of tectonic stability, particularly the absence of recent faulting, is an important factor in siting and designing various earthquake-sensitive engineered structures. Several organizations concerned with planning such structures within the Hanford Site have carried out or commissioned extensive geological and geophysical surveys in the vicinity. During the last 10 years, the organizations principally involved have been Rockwell Hanford Operations, Washington Public Power Supply System, and Battelle Northwest Laboratory, all located in Richland, Wash., and Northwest Energy Services Company, Kirkland, Wash. Many of their reports are available to the public, and some are referenced in this paper.

This report augments, in a small way, the studies mentioned above by calling special attention to certain features along this part of the Columbia River that suggest tectonic stability and the absence of faulting during part or all of Quaternary time. The report is based on visual surface observations, augmented locally by study of aerial photos. The observations were made in the course of a study of ground failures and ground-failure hazards in the Columbia River valley that is still in progress.

Geologic Setting

The area studied is in the west-central part of the Columbia Plateau, a physiographic province that is commonly defined as being coextensive with the huge, lenticular accumulation of Miocene plateau basalt, known as the Columbia River Basalt Group, that underlies southeastern Washington and parts of northern Oregon and western Idaho. Flows of the Yakima Basalt subgroup, the

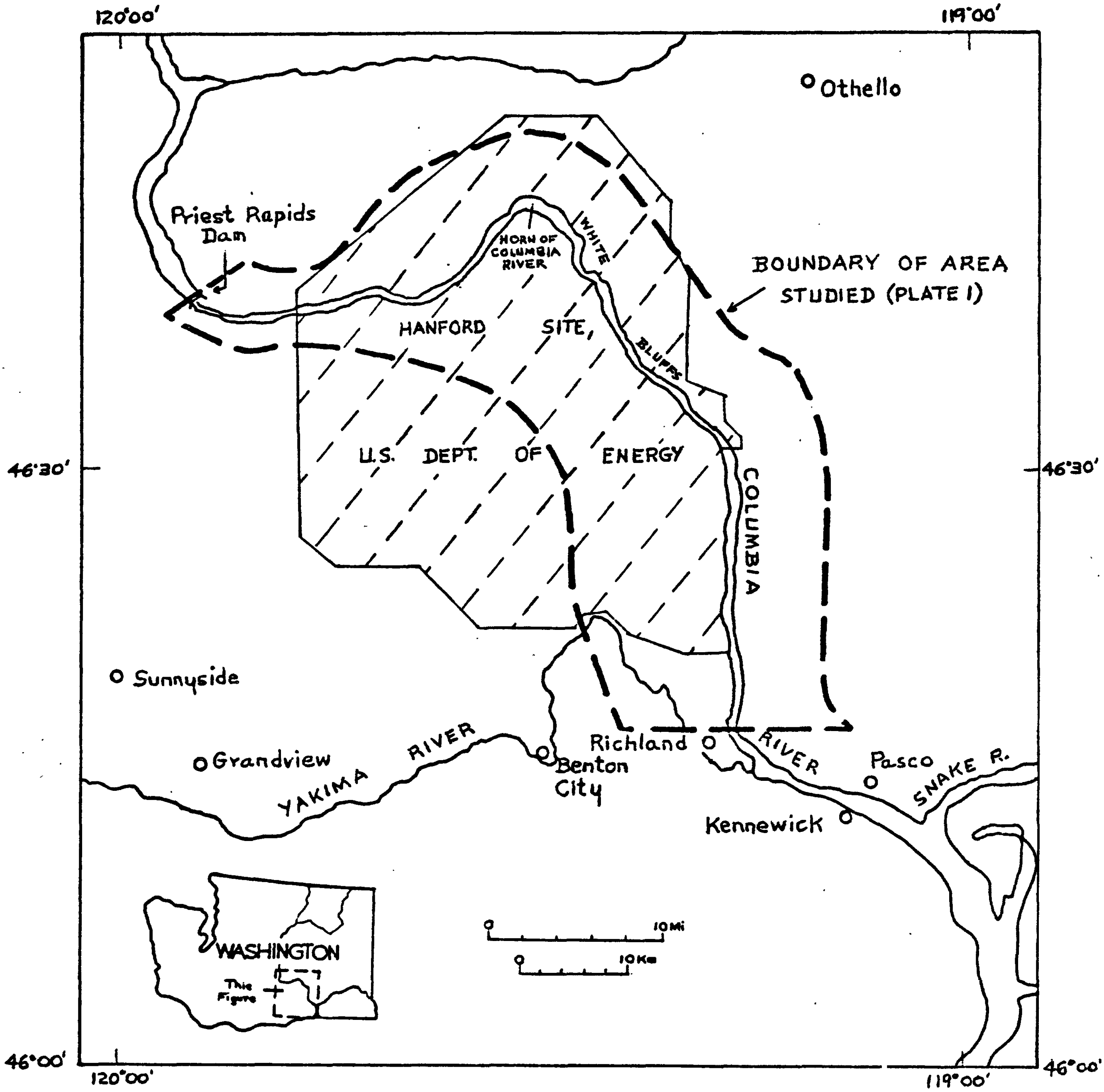

Figure 1.--Map showing the location of the study area, which is outlined in heavy dashes.

upper part of the group, crop out in several parts of the study area (pl. 1), mainly in the form of anticlinal ridges.

Where the basalt does not crop out, it is generally overlain by fluvial and subordinate lacustrine deposits of late Miocene(?) to late Pleistocene age. The late Miocene(?) and Pliocene Ringold Formation, with a maximum thickness of about 1,200 ft (365 m) (Newcomb and others, 1972), consists of very weakly to moderately indurated, commonly well-bedded siltstone, sandstone, and claystone and, subordinately, of a moderately indurated, rather massive conglomerate. Along the eastern and northern sides of the Columbia River, from several miles north of Richland northward to the great "horn" of the river, rocks of the Ringold Formation crop out in bluffs, 120-550 ft (37-168 m) high, facing the river (pl. 1; fig. 2). The northern part of these bluffs has long been known as the "White Bluffs," owing to the light colors of the Ringold exposures.

Everywhere in the study area west and south of the bluffs of Ringold Formation the upper part of that formation has been eroded away, and the remaining lower part is buried beneath glaciofluvial gravel, sand, and minor silt deposited by huge Pleistocene floods (Bretz and others, 1956; Bretz, 1969; Baker and Nummedal, 1978). The flood deposits are some 50-200 ft (15-60 m) thick over most of that part of the area. In some locations, they form the present ground surface or are within a few feet of it, and some of these deposits preserve the forms of huge, smooth-surfaced bars, deposited and shaped by one or more of the latest floods (Bretz and others, 1956). Other glaciofluvial sediments mantle the Ringold Formation beneath much of the upland surface east and north of the bluffs. They include more silt and less gravel and tend to be thinner than those to the west and south.

Surficial material deposited in the area since the late Pleistocene floods includes abundant eolian sand and silt, reworked from the Ringold and glaciofluvial sediments by prevailing westerly winds, and local alluvium, colluvium, mudflows, talus, and landslides. The windblown sediment, commonly 3-30 ft (1-10 m) thick and locally thicker, forms virtually all of the ground surface on the upland east and north of the bluffs of Ringold Formation, concealing that formation and commonly some glaciofluvial sediments there. It forms most of the surface west and south of the bluffs, where it widely but discontinuously conceals the flood sediments. Sand in both areas locally forms active dunes.

The degree of deformation of the rocks and sediments in the study area decreases upward in the stratigraphic section. The Miocene basalt is locally folded into eastward-attenuating anticlines, commonly accompanied by faults. In the western part of the area, the concealed lower part of the Ringold Formation is gently folded along lines of folding in the basalt, the intensity of folding decreasing upward in the formation (Webster and Crosby, 1981). The no more than slight deformation of the Ringold in the bluffs east of the Columbia River is discussed below. Within the study area, the only recorded deformation of glaciofluvial deposits that may be of tectonic origin is the very minor faulting of late Pleistocene gravel at Gable Mountain (pl. 1, south of the "horn" of the Columbia River) (Golder Associates, Inc., 1981); but it should be noted that, apart from artificial excavations, these deposits rarely form clean exposures in which continuity of their strata can be confirmed.

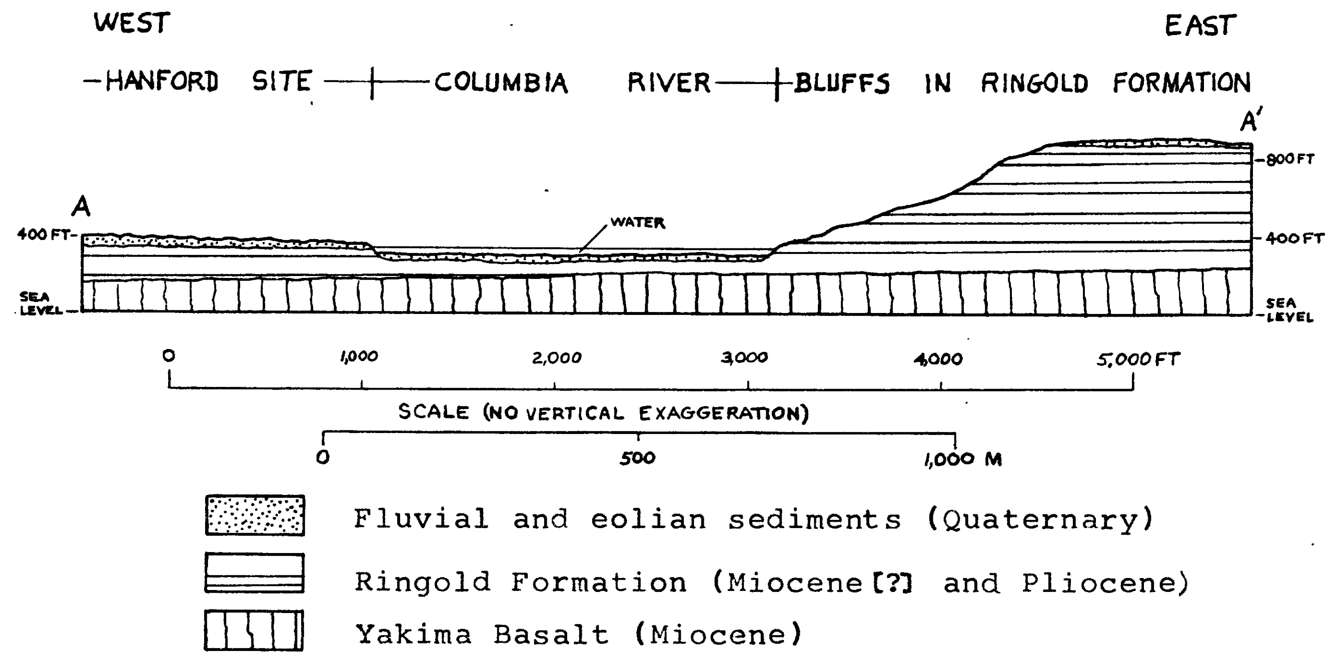

Figure 2.--Diagrammatic cross section of the Columbia River about 1 mi south of Taylor Flat.

EVIDENCE OF TECTONIC STABILITY

The near horizontality and continuity of strata in the upper Ringold Formation and of the calcrete that caps that formation in the bluffs along the east margin of the study area (pl. 1) and the apparent absence of any deformation of several late Pleistocene surfaces of deposition strongly suggest that there has been little or no tectonic deformation of large parts of the area, during all or at least part of Quaternary time. The evidence from the Ringold Formation and the calcrete is of greatest significance, because these rocks are much older than the late Pleistocene surfaces.

Most of the basalt exposed in the study area was highly deformed in Miocene and Pliocene time. Proof of continuity of such deformed basalt would require much more intensive examination than that applied in this study, and definite continuity of lava is indicated at only one place on plate 1, near the southern end of the area.

Slight Deformation of the Ringold Formation and Calcrete in the Bluffs Along the East Side of The Columbia River

So far as is known, the basalt underlying the bluffs of Ringold Formation along the east and north sides of the Columbia River (pl. 1) is little deformed (Myers and others, 1979, pl. III-4a). The beds in the upper part of the formation, which are well exposed in the bluffs, are almost horizontal and apparently have remained virtually undeformed since their deposition in Pliocene time. They show only a general, slight westward dip and probably some minor warping that decreases upward in the formation (Brown and McConiga, 1960; Grolier and Bingham, 1978).

Though many beds in the Ringold Formation are less continuous than one might presume in viewing the banded faces of the bluffs from a distance, some individual beds and, more commonly, sequences of beds can be identified for several miles (Washington Public Power Supply System, 1981, figs. 2.5-36 and 2.5-37), and one bed is reported to have been traced for 19 mi (30 km) (Brown and McConiga, 1960). This continuity of layers within the formation, supplemented by continuity of the layer of calcrete common at its top, provides excellent control on the possibility that faults have cut across and offset these bluff rocks since their deposition.

The layer of calcrete at the top is extensively, but not everywhere, preserved in the bluffs and farther east and north. It has been interpreted as having formed during a long Pleistocene dry period, prior to the catastrophic glaciofluvial flooding late in the epoch that locally removed it (Newcomb, 1958; Grolier and Bingham, 1978). The calcrete has attained at least stage IV in the sequences of carbonate deposition in calcic soils developed by Gile and others (1966) and Bachman and Machette (1977) in the southwestern United States. Because of such variables as climate, parent materials, and carbonate supply, the ages of similarly developed calcretes cannot be projected casually from one region to another, but it is reasonable to believe, on the basis of age determinations on calcretes in the southwestern United States (Bachman and Machette, 1977, fig. 18) that the calcrete at the top of the bluffs here is more than 100,000 years old. A thorium/uranium age of more than 500,000 years for this calcrete has been reported to Rockwell Hanford Operations (Tallman and others, 1981), but the reliability of thorium/uranium in differentiating ages greater than 300,000 years in such impure calcareous material is questionable.

Lines indicating continuity of Ringold strata and of calcrete have been drawn on plate 1 on the basis of distant but careful observations of the bluffs from vantage points on both sides of the river, augmented by local photo study and inspection of selected outcrops. This may be the first time that all layering has been observed systematically and continuously along the entire length of the bluffs. Lines based on continuity of calcrete are drawn only where the Ringold is poorly exposed.

No evidence for faulting of the Ringold or the calcrete was seen along the entire length of the bluffs, from the vicinity of Johnson Island north to the horn of the river. The continuity lines are almost continuous throughout this distance, and there is no evidence for faulting at gaps in the lines--gaps merely indicate poor exposure of the bluff rocks. The similar altitudes of exposures of a distinctive tuff bed in the Ringold north and south of the large gap about a mile south of Savage Island do not indicate any offset. The lines could be refined and all gaps in them probably closed by use of surveying and shallow drilling or geophysical procedures. North of the horn of the river, such techniques could probably establish extension of virtually undeformed Ringold westward from its westernmost outcrops, beneath a cover of windblown sand.

Various magnetic, gravity, and topographic lineaments have been reported in and near the study area (for example, Washington Public Power Supply System, 1977; Myers and others, 1979; Puget Sound Power and Light Co., 1981), and some of these extend or project across the continuity lines on plate 1. These lines may be especially useful in assessing the nature, extents, and ages of geologic features that may be associated with such lineaments.

Undeformed Late Pleistocene Surfaces

The huge Pleistocene floods that poured across the Columbia Plateau in eastern Washington and down the valley of the Columbia River deposited gravel, sand, and silt over most of the study area. In large part, this deposition and accompanying local erosion was too rapid and variable to produce well-defined terraces. Locally, however, the smooth tops of large flood bars within the miles-wide flood channel and the flat upper surfaces of slack-water deposits on the margins of the channel are preserved and exposed. These surfaces probably represent the latest of the Pleistocene floods, which are believed to have occurred about 13,000 years ago (Mullineaux and others, 1977, 1978). Six such surfaces, outstanding for their low relief, large area, and excellent exposure, are delimited and labeled with capital letters on plate 1. One, surface A, is in the southeast corner of the study area, where the flood channel broadened eastward. Five, surfaces B-F, are near the north end of the area, where floodwaters that surged out of the constricted channel through the Saddle Mountains, farther north, were turned eastward by Umtanum Ridge (pl. 1, south of Columbia River) and spread out over the northern part of the present Hanford Site. All six are remarkably even, have imperceptible to gentle slopes, are more than 40 ft (12 m) above present normal river level, are almost bare or mantled only thinly by Holocene deposits, and have areas of several square miles. All show only slight soil development, including, locally, calcareous deposits on the lower parts of stones. All six surfaces are almost certainly of late Pleistocene age and are significant in suggesting the absence, in their locations, of more than slight faulting or deformation of any kind in the past 12,000 years. Further restriction on deformation probably could be achieved by detailed surveying of these surfaces.

Surface A is underlain by gravelly basaltic sand, the top of which has been reworked by wind. It shows a very even, unbroken profile when viewed from the west side of the Columbia River. Surfaces B, C, and D are the even, essentially horizontal upper surfaces of flood bars (Bretz and others, 1956), underlain by gravel that is commonly mantled by less than 2 ft (0.6 m) of sand. Surface E is underlain by silt and sand deposited by slack water of the flooded river in the lee of the large bar adjoining it on the west. The surface is very even, the small irregularities resulting chiefly from variable distribution of wind-worked sand. Within 1.5 m (2.4 km) of the bluff at its southern edge, a direction of slope is commonly indiscernible to the eye; farther north, the slope is gently southward. Surface F is the southwest-sloping upper surface of a huge bar of gravel and sand, of which only the southern part is included in the area here mapped. Its strikingly smooth, apparently unbroken slope is best observed from the south side of the river. Views of the bluffs at the southern edges of surfaces C and F suggest that some layers in the gravel and sand may be fairly continuous. Such layers could, perhaps, be traced by drilling or geophysical techniques, if it is important to substantiate the apparent absence of deformation.

CONCLUSIONS

Exposures of basalt of Miocene age, the Ringold Formation of Pliocene age, calcrete of Pleistocene age (more than 100,000 years old), and smooth topographic surfaces of late Pleistocene age indicate that there has been very little to no deformation over large parts of the study area since these rocks and surfaces were formed.

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