
Title: Structure and Evolution of the Horse Heaven Hills in South-Central Washington.

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The Horse Heaven Hills uplift in south-central Washington consists of distinct northwest and northeast trends which merge in the lower Yakima Valley. The northwest trend is adjacent to and parallels the Rattlesnake-Wallula alignment (RAW; a part of the Olympic-Wallowa lineament). The northwest trend and northeast trend consist of aligned or en echelon anticlines and monoclines whose axes are generally oriented in the direction of the trend. At the intersection,
folds in the northeast trend plunge onto and are terminated by folds of the northwest trend.

The crest of the Horse Heaven Hills uplift within both trends is composed of a series of asymmetric, north vergent, eroded, usually double-hinged anticlines or monoclines. Some of these "major" anticlines and monoclines are paralleled to the immediate north by lower-relief anticlines or monoclines. All anticlines approach monoclines in geometry and often change to a monoclinal geometry along their length.

In both trends, reverse faults commonly parallel the axes of folds within the tightly folded hinge zones. Tear faults cut across the northern limbs of the anticlines and monoclines and are coincident with marked changes in the wavelength of a fold or a change in the trend of a fold. Layer-parallel faults commonly exist along steeply-dipping stratigraphic contacts or zones of preferred weakness in intraflow structures. Most of these faults appear to reflect strain from folding.

Isopach maps of Columbia River basalt (CRB) flows/Ellensburg Formation interbeds and paleodrainage maps of the ancestral Columbia River system indicate that deformation occurred simultaneously and coincident with both trends of the Horse Heaven Hills uplift, the lower Yakima Valley syncline, the Piening syncline (within the Horse Heaven Plateau), and the Hog Ranch-Naneum Ridge anticline (within the lower Yakima Valley) since at least Roza time. Data are not available for determining the timing and location of deformation prior to Roza time, nor does the geologic record allow for a detailed description of
the growth history after CRB time, except that the observed present structural relief along the Horse Heaven Hills uplift developed after Elephant Mountain time (10.5 m.y.B.P.).

Relief between the Horse Heaven Hills uplift and the lower Yakima Valley syncline developed at a rate of less than approximately 70 m/m.y., during Wanapum and Saddle Mountains time (combined rate of vertical uplift and subsidence). Growth rates appear to decrease during Wanapum and Saddle Mountains time. Growth rates extrapolated to the present approximate the cumulative relief developed since Wanapum time indicating the possibility that folds developed at a uniform rate since CRB time to the present. However, the data from this study do not preclude the variability of growth rates in post CRB time.

Data from this study suggest that tectonic models which directly or indirectly pertain to the origin of the Horse Heaven Hills uplift might be constrained by: (1) the predominance of monoclinal or near-monoclinal fold geometries and reverse faults along both the northwest and northeast trends; (2) preliminary data which suggest clockwise rotation has occurred along folds of both trends; (3) folds along both trends were developing simultaneously and at similar rates (at least during Wanapum and Saddle Mountains time); (4) folds along the northwest trend of the Horse Heaven Hills uplift are genetically related to and formed simultaneously with at least some folds along the RAW; (5) the uplift was developing simultaneously with the north-northwest-trending Hog Ranch-Naneum Ridge anticline as well as other Yakima folds during at least CRB time. It is proposed that folds of both
trends of the Horse Heaven Hills uplift were generated by the same tectonic processes.