Kinematic Modeling of the Yakima Fold and Thrust Belt at Selah Butte, Umtanum Ridge, and Manastash Ridge

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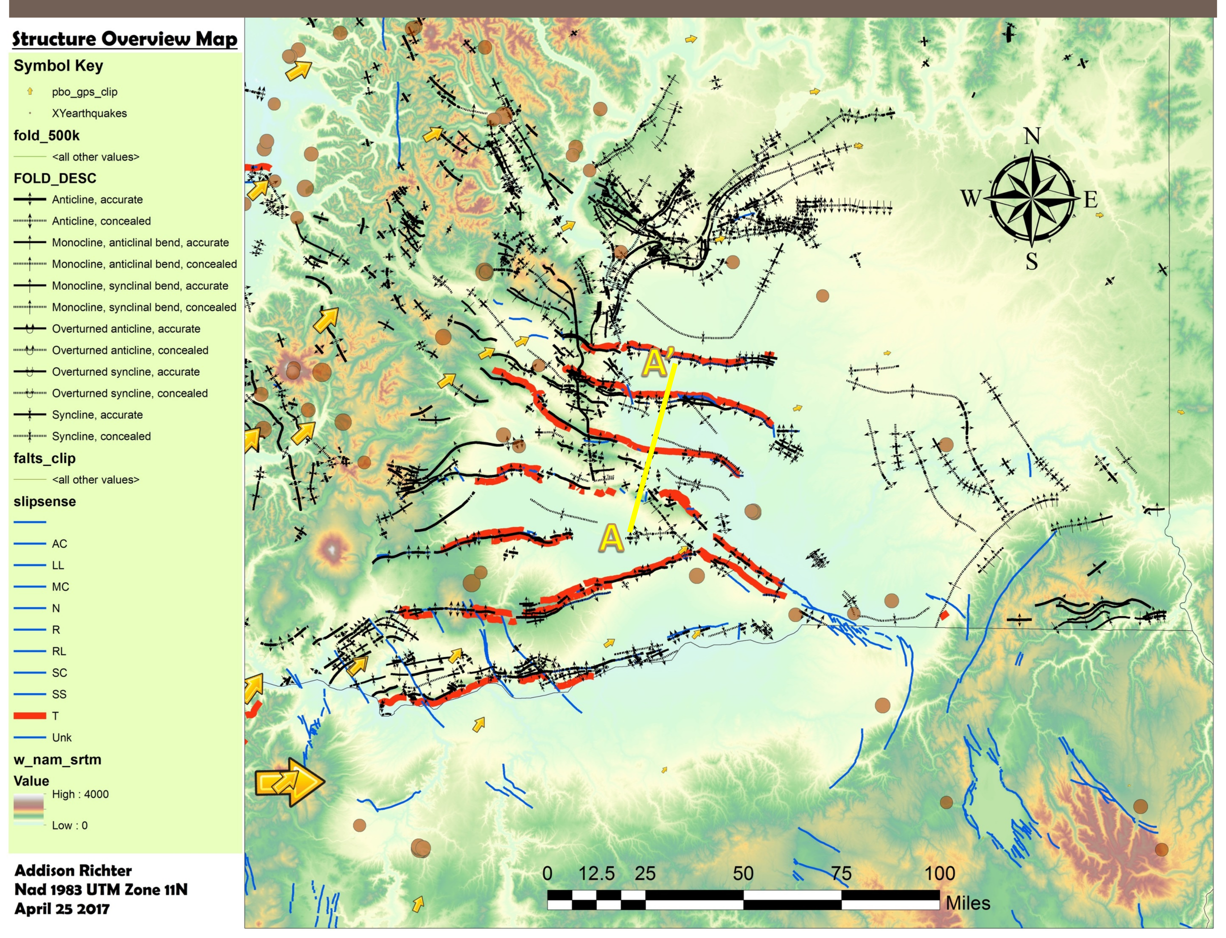
INTRODUCTION

In central Washington there is a set of seismogenic thrust/reverse faults and associated folds called the Yakima Fold and Thrust Belt (YFTB). Understanding sub-surface fault geometry of the YFTB is directly linked to assessing seismic potential, as earthquake magnitude scales with fault surface area. Three faults were selected for this study: 1) Selah Butte thrust fault, 2) Umtanum Ridge thrust fault, and 3) Manastash Ridge thrust fault to test whether surface fold geometries can be modeled with either (a) shallowly- dipping listric thrust faults with high surface area; or (b) steep, curviplanar reverse faults with a low surface area. Kinematic models were created using published geologic and seismic data. Surface data were compiled in ArcGIS to analyze deformation of Columbia River Basalt flows (CRBs) to interpret the underlying fault geometries within the brittle crust. CRB contacts were digitized to create contoured structure surfaces. These surfaces were combined with outcrop and orientation data and used in 2D MOVE to produce line-length balanced cross-section interpretations of fault geometries at depth.

STRUCTURE OVERVIEW MAP



METHODS

The procedure for producing line-length balanced cross-section interpretations of fault geometries at depth followed 4 main steps:

- Compile Strike/Dip data into GIS
- Combine strike/dip data with outcrop and orientation data in MOVE
- Create new fault geometries referencing existing published work (Miller, 2014)
- Compare structure of new fault geometries with existing geometries and end member hypothesis.

RESULTS

Faults 1, 2, and 3 worked best with a fault bend fold method to model 2D deformation. Cross sections with three working fault geometries produced with 2D MOVE are shown in Figure 1. The pink form lines represent the CRB contacts; the gray lines are form lines to highlight deformation; and the red symbols are strike/dip measurements oriented to show bedding dip direction. An enlarged cross section through the Umtanum Ridge (proposed fault 2 geometry) is shown in Figure 1a.

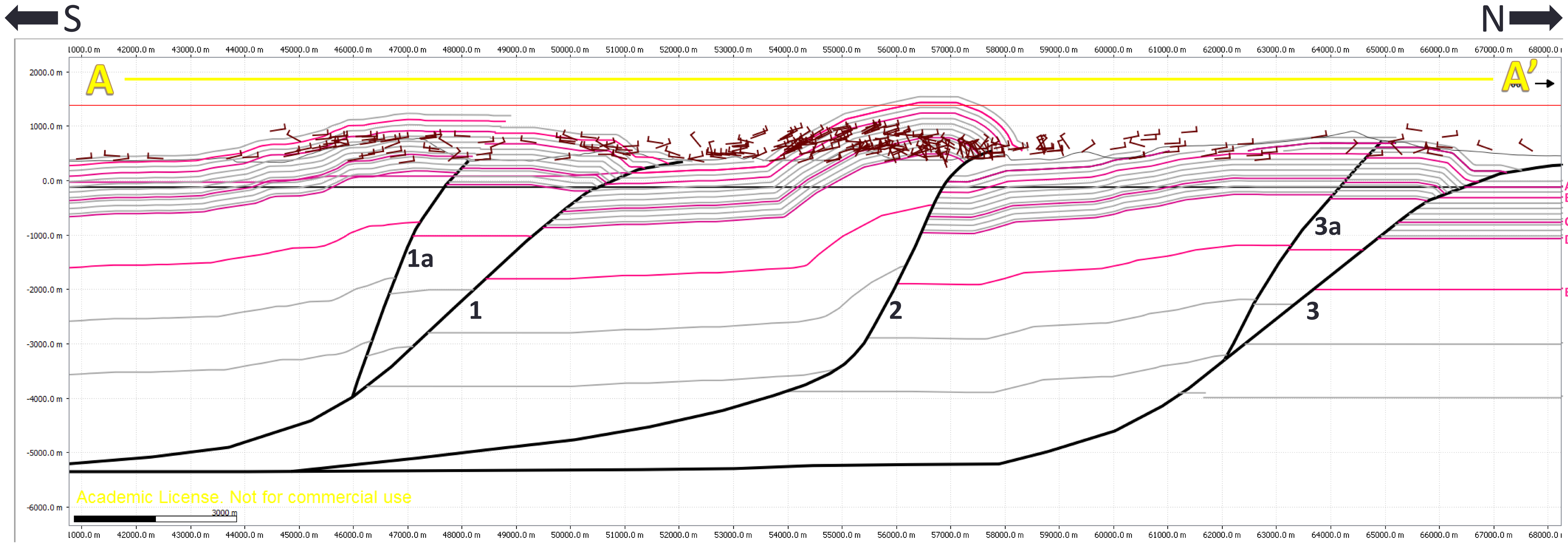


Figure 1. Cross sections with three working fault geometries produced with 2D MOVE.

Table 1. Fault ID, method of deformation, displacement, and dip angle.

Fault	Method of Deformation	Total Displacement	Approximate Dip Angle
1	Fault bend fold	1 km	>4 km: 10° 4 km – 1 km: 45° 1 km – 0 km: 40° 0 km – 300 m: 5°
1a	Fault parallel fold	100 m	3 km – 0 km: 70° 0 km – 400 m: 60°
2	Fault bend fold	1 km	>5 km: 5° 5 km – 4 km: 15° 4 km – 0 km: 60° 0 km – 500 m: 30°
3	Fault bend fold	1 km	>5 km: 5° 5 km – 4 km: 20° 4 km – 0 km: 40° 0 km – 400 m: 15°
3a	Fault parallel fold	300 m	3 km – 700 m: 55°

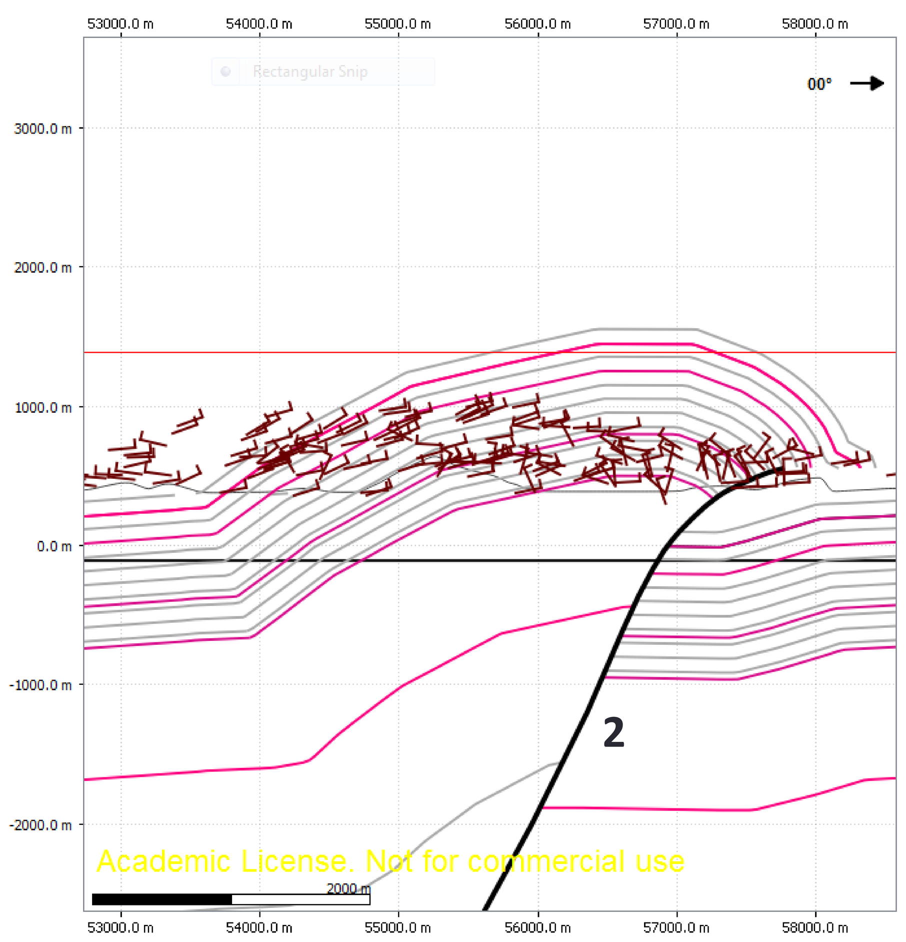


Figure 1a. Enlarged cross section through Umtanum Ridge, showing proposed fault 2 geometry (fault bend fold).

Unit Name

A. Upper flows of Columbia River Basalt Group

B. Frenchman Springs Member, Wanapum Basalt

C. Upper flows of normal polarity, Grande Ronde Basalt

D. Upper flows of reversed polarity, Grande Ronde Basalt

E. Base of the basalt

CONCLUSIONS

Figure 2 presents a schematic model of thin-skinned fault geometry underneath faults 1, 2, and 3 with topography, strike-dip data, and occurrence of fault traces. The fault geometries produced are consistent with thin-skinned deformation theories, and are therefore more subject to seismic hazard due to increased surface area. This conclusion is consistent with some, but not all published research, as the origin of the YFTB remains heavily debated. However, a better understanding of fault geometries can aid in the prediction and analysis of seismic hazard, which is of great concern due to the proximity of the YFTB to extensive infrastructure such as the Hanford nuclear site and six major dams.

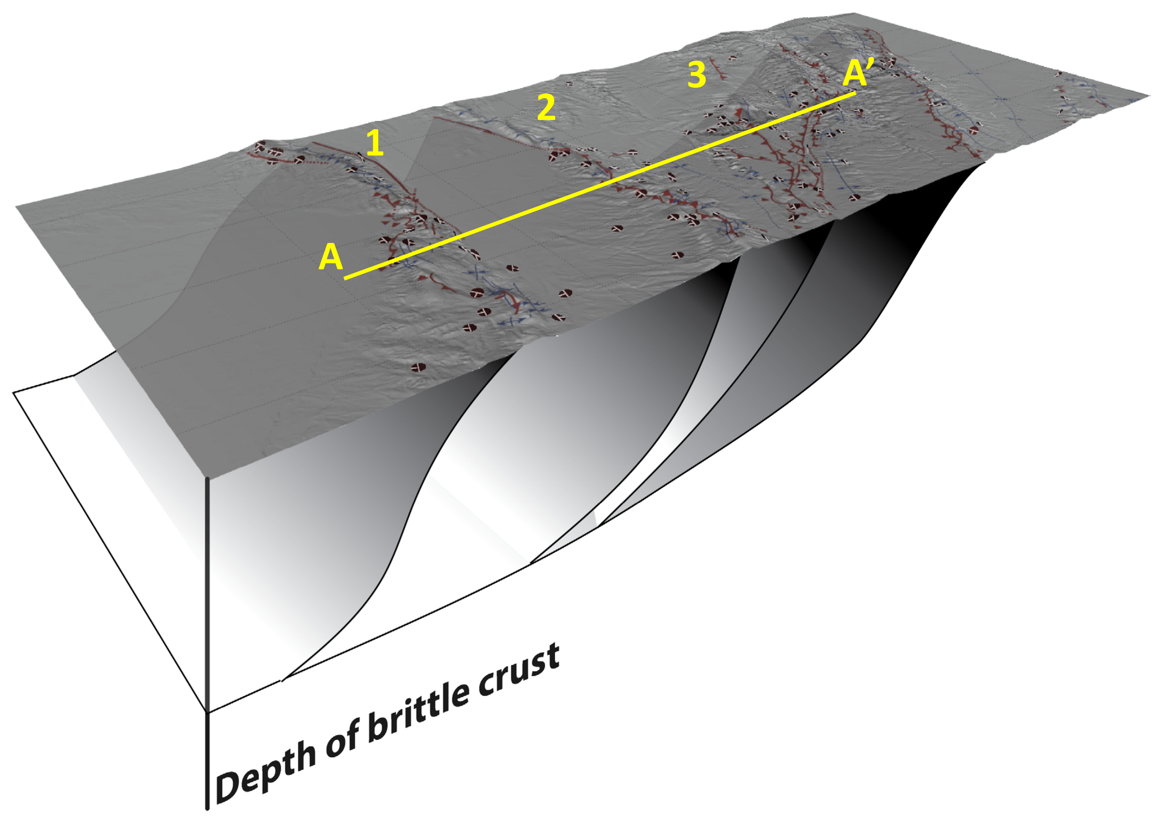


Figure 2. Schematic model of thin-skinned fault geometry underneath faults 1, 2, and 3 with topography, strike-dip data, and occurrence of fault trace

REFERENCES

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