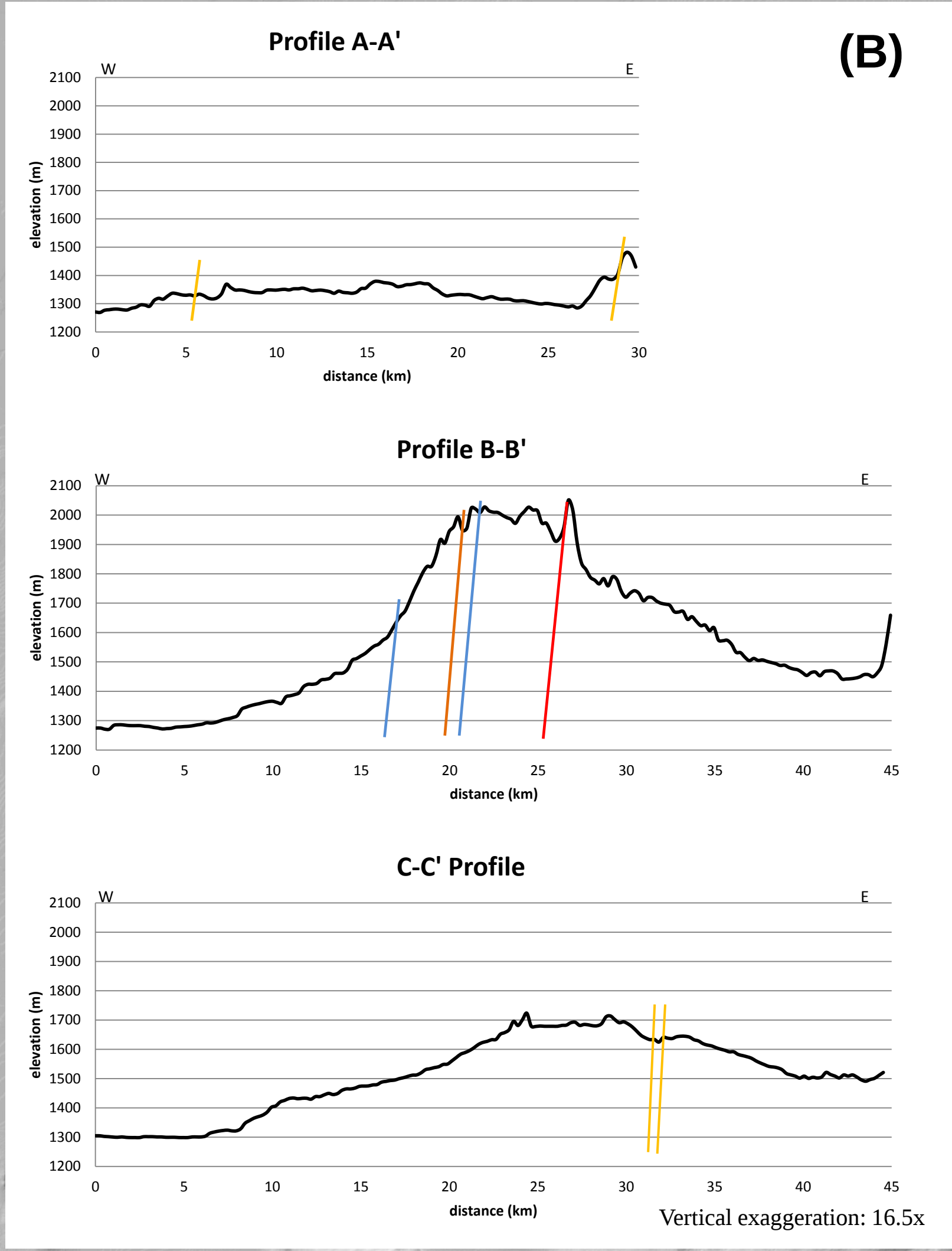
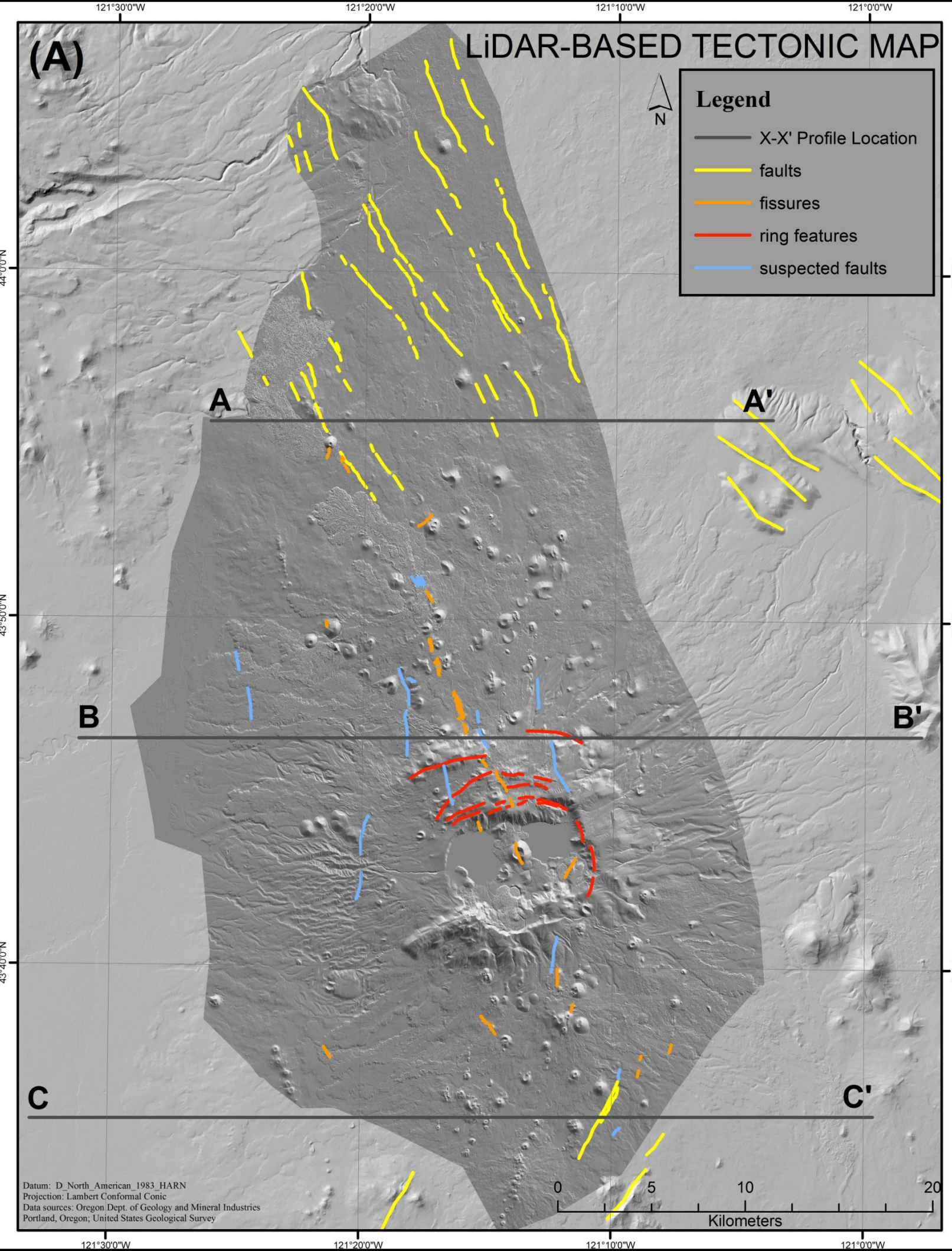
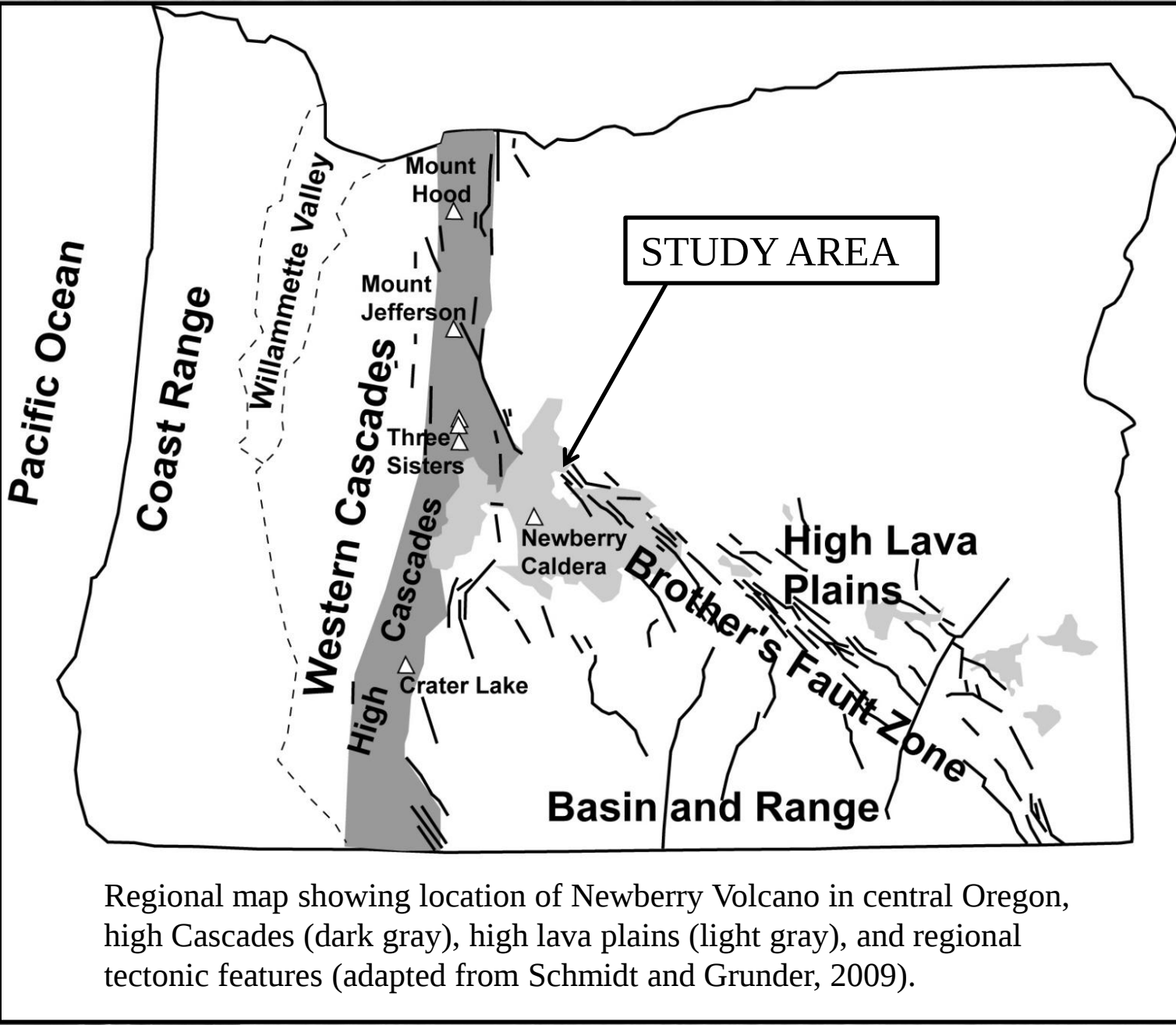


ORIGIN OF FAULTS, FISSURES AND VOLCANIC VENT ALIGNMENTS AT A STRUCTURAL TRIPLE JUNCTION, NEWBERRY VOLCANO, CENTRAL OREGON

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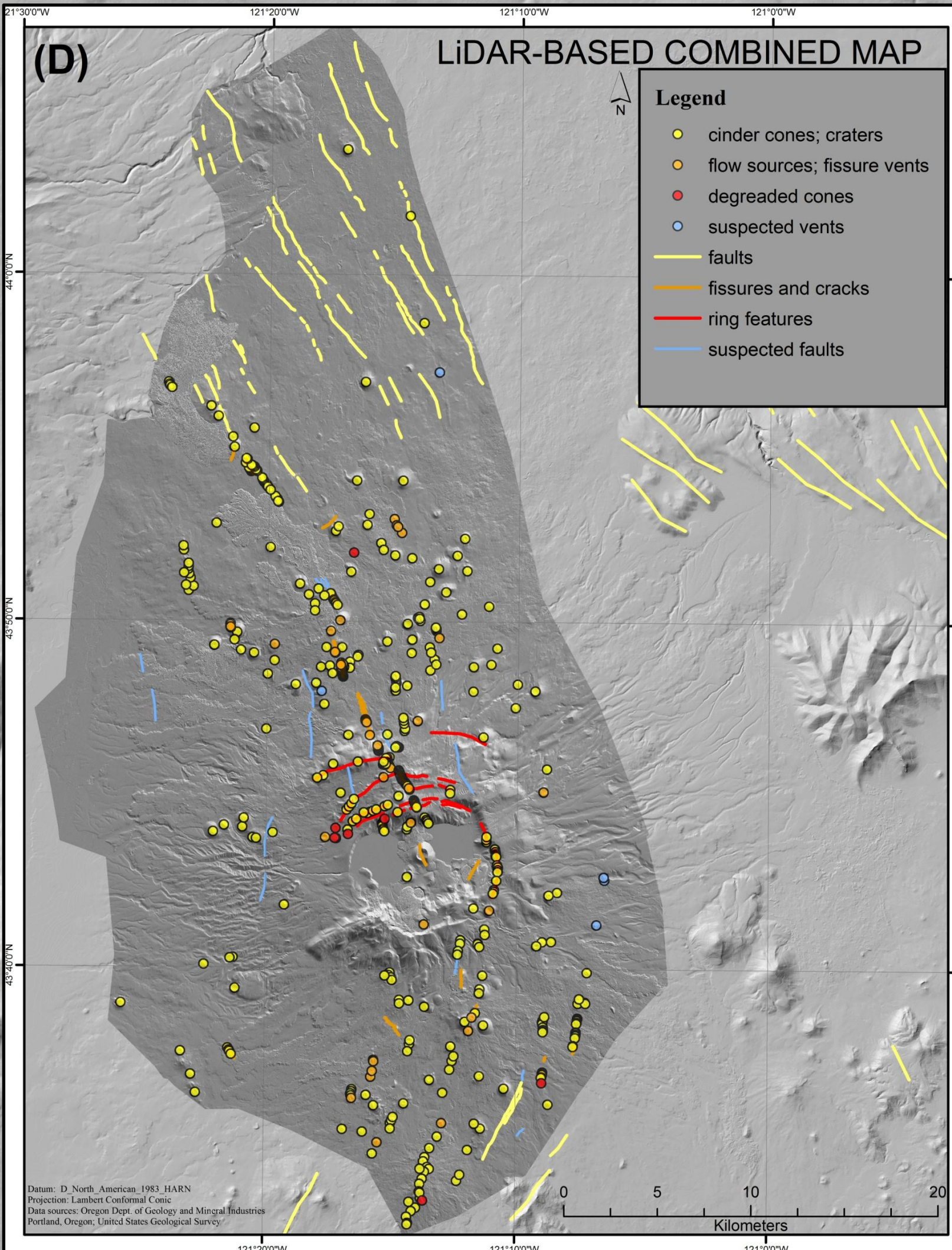
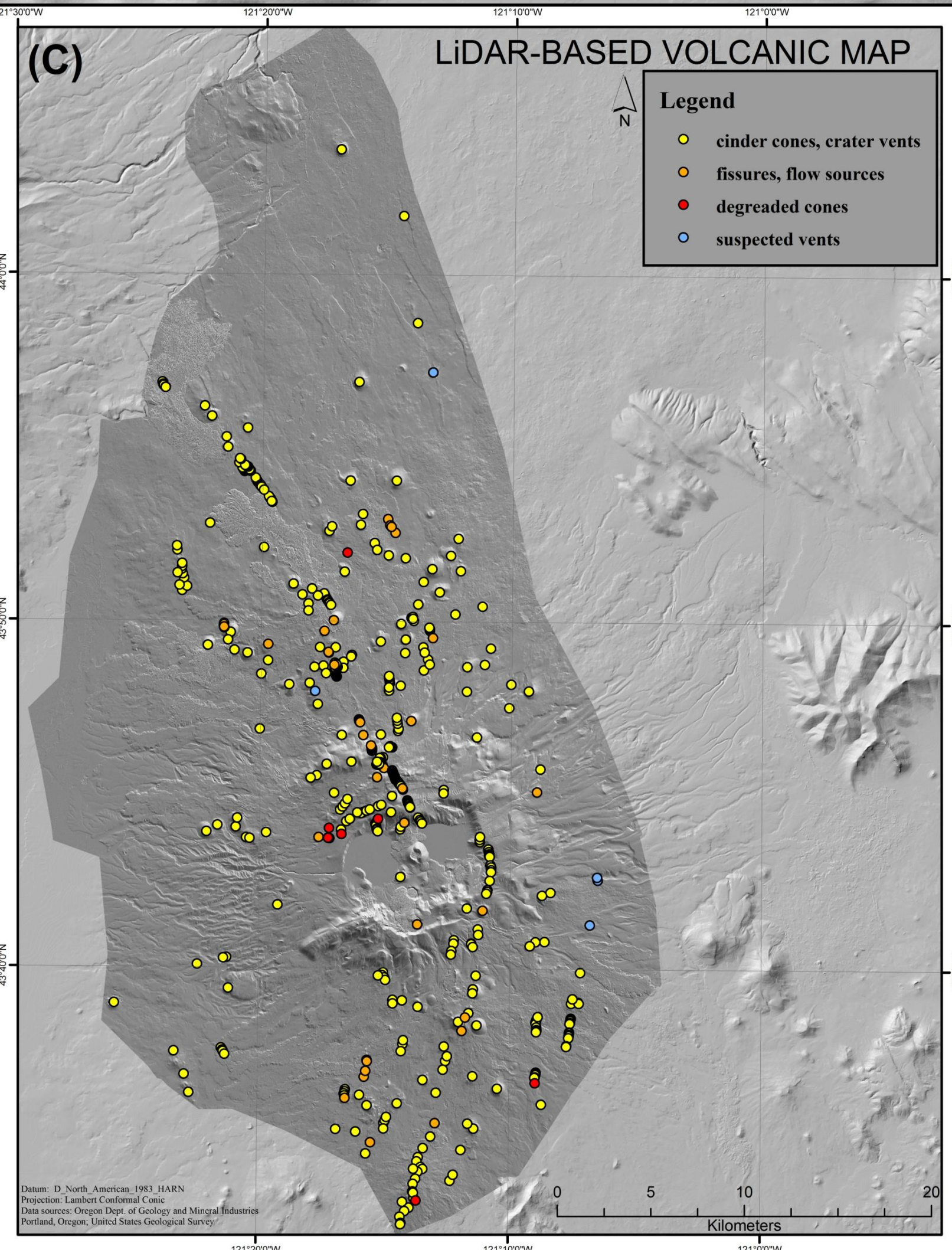
ABSTRACT:
Newberry Volcano in central Oregon formed at the intersection of extensional fault systems defining the Basin and Range extensional province, the Cascades Graben and the Brothers Fault Zone. A unique structural orientation characterizes each fault system. Basin and Range faults trend north, northeast and northwest. The Cascade Graben is defined by north-trending faults. The Brothers Fault Zone is defined by northwest trending faults. In this study we mapped faults, fissures, and vent alignments using LiDAR topographic data to investigate the stress regime of the volcanic edifice and surrounding environs. We seek to better understand the relationship between volcanic and tectonic signatures of stress regime and sites for proposed development of geothermal energy. Stress regime across a volcanic edifice reflects some combination of sources from plate motion, magma chambers at depth, and topography of the edifice itself. Orientation of faults, fissures and volcanic vent (cinder cones and volcanic vents typically parallel fault trend) alignments vary systematically around the volcanic edifice at Newberry. On the north side of the volcano, faults, fissures and volcanic vents generally trend north-northwest. Ring dikes, fractures and vents follow the rim defining the edge of the caldera. South of the caldera, faults, fissures and volcanic vents trend northeast. Whereas the ring dike and fault system around the caldera rim clearly reflect volcanic processes, the faults and volcanic features on the north side of the volcano parallel Basin and Range faults away from the edifice and apparently merge northward with the Cascade Graben fault system. Thus we conclude that these are tectonic faults formed in a stress regime controlled by plate motions. In contrast, the northeast trending faults in the south are enigmatic and unlike any other faults found regionally. One possible explanation is that these faults represent one arm of a radial fault system, the north arm of which has been reactivated as the result of overprinting by regional crustal extension. Geothermal prospects occur in the northern fault system, which reflects a tectonic rather than a volcanically or topographically controlled stress regime.



(A) LIDAR-BASED TECTONIC MAP:
Prominent topographic scarps identify faults in the LiDAR data (yellow lines). Faults and fissures follow three main trends at Newberry. North of the caldera lineaments generally trend north-northwest, corresponding to Basin and Range regional fabric (A; yellow). These faults merge to the northwest with the Tumalo Fault Zone, a northwest trending system of normal faults indicating extensional tectonic control in the area (Priest, 1990). At the caldera, fault trend changes to a more north-trending orientation. Surrounding the summit caldera, a second set of faults interpreted as ring faults and dikes encircle the caldera (red), which are cross-cut by the NNW trending fault fabric on the north rim. South of the caldera, a third fault population trend northeast, a trend that does not correspond to any other fault orientation in the northwest Basin ad Range (Donath, 1962; Pezzopane and

Weldon, 1993). These lineaments become more north-trending in close proximity to the Newberry edifice where they cross-cut the caldera ring structures. Two northwest trending fissures with aligned crater vents are noted in the southwest quadrant of the study area (blue arrows).

(B) Topographic profiles over the edifice reveal the difference in elevation between the more elevated eastern and topographically lower western flanks of the Newberry edifice. The difference in elevation suggests that the caldera is offset by a down-to-the-west fault system (blue, panel (A)) that is obscured by deposits forming the western flank of the caldera (A).



(C) LIDAR-BASED VOLCANIC MAP:
Cinder cones and crater vents generally follow the three main structural trends of faults and fissures over the edifice at Newberry. North of the caldera, cinder cones and crater vents form linear arrays trending north-northwest along major faults, although not all vents appear aligned or follow faults. At the caldera summit, cones and crater vents follow the curvilinear structural trends of the ring fault system (A). South of the caldera cinder cones and crater vents follow the main northeast structural trend of faults and fissures. Two northwest trending fissures with aligned crater vents are noted in the southwest quadrant of the study area.

(D) LIDAR-BASED COMBINED MAP:
Tectonic and volcanic features over the edifice at Newberry show a strong north-northwest trend of faults (yellow, confident; blue, inferred), fissures (orange) and vents north of the caldera (C). These features turn to a more north-trending orientation as they approach the caldera. South of the caldera, faults and elongate vents follow a northeast trend, which becomes more north-oriented toward the caldera. Ring dikes and faults at the caldera show distinct alignments with cones and crater vents. Structural trends continuing from both the north and south ends of the edifice trend north and cross-cut ring faults observed at the caldera.

CONCLUSIONS:
Regional stresses associated with the Newberry caldera reflect both the extensional systems of the northwest Basin and Range and the Cascade graben. Change in fault trend in the vicinity of the caldera, however, suggests that the mass of the edifice controls the stress orientation near the volcano. Both the NE-trending faults in the south and the NNW-trending faults in the north change to N-trending where they cross the flanks and summit of the caldera (D). The N trend near the volcano suggests an E-W orientation to the stress field locally, which contrasts with the NNW orientation inferred in other studies of the northwest Basin and Range (Crider, 2001; Donath, 1962; Pezzopane and Weldon, 1993). The E-W extension direction on the volcano is confirmed by the breakout directions observed in BHTV images at depth in NWG 55-29 (Davatezes and Hickman, 2011). Because these faults merge with regionally developed fault systems away from the volcano, the faults are inferred to represent tectonic faults. Topographic profiles reveal an overall down-to-the-west sense of asymmetry across the edifice (B). Thus, the caldera appears to be extended by down-to-the-west normal faults, both across the crest of the caldera and potentially on the western flank of the caldera as well (blue faults). The poorly-exposed faults on the western flank may be the more significant of the two fault systems given the ~200 m difference in elevation from east to west across the edifice (B). These fault systems both cut the caldera and associated ring fractures as well as having served as conduits for eruptions that created aligned cinder cones, fissures, and associated lava flows.

References:
Crider, 2001. *Oblique slip and the geometry of normal-fault linkage: mechanics and a case study from the Basin and Range in Oregon*. Journal of Structural Geology, Vol. 23.
Davatezes and Hickman, 2011. *Preliminary Analysis of Stress in the Newberry EGS Well NWG 55-29*. GRC Transactions, Vol. 35, 2011.
Donath, 1962. *Analysis of basin-range structure, south-central Oregon*. Geological Society of America Bulletin, Vol. 73.
Pezzopane and Weldon, 1993. *Tectonic Role of Active Faulting in Central Oregon*. Tectonics, Vol. 12, No. 5, October, 1993.
Priest, 1990. *Volcanic and Tectonic Evolution of the Cascade Volcanic Arc, Central Oregon*. Journal of Geophysical Research, Vol. 95, No. B12, November 10, 1990.
Schmidt and Grunder, 2009. *The evolution of North Sister: A volcano shaped by extension and ice in central Oregon Cascade Arc*, Geological Society of America Bulletin, Vol. 121, No. 5-6, May/June 2009.

Acknowledgements:
Special thanks to Drs. Anita Grunder and John Dilles and the OSU Dept. of Geosciences; AltaRock Energy, Inc., and Dr. Tom Eastler at the University of Maine at Farmington, without whom I never would have found terrain analysis and LiDAR remotely interesting.

This material is based upon work supported by the Department of Energy under Award Number DE-EE0002777. *Disclaimer:* This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

