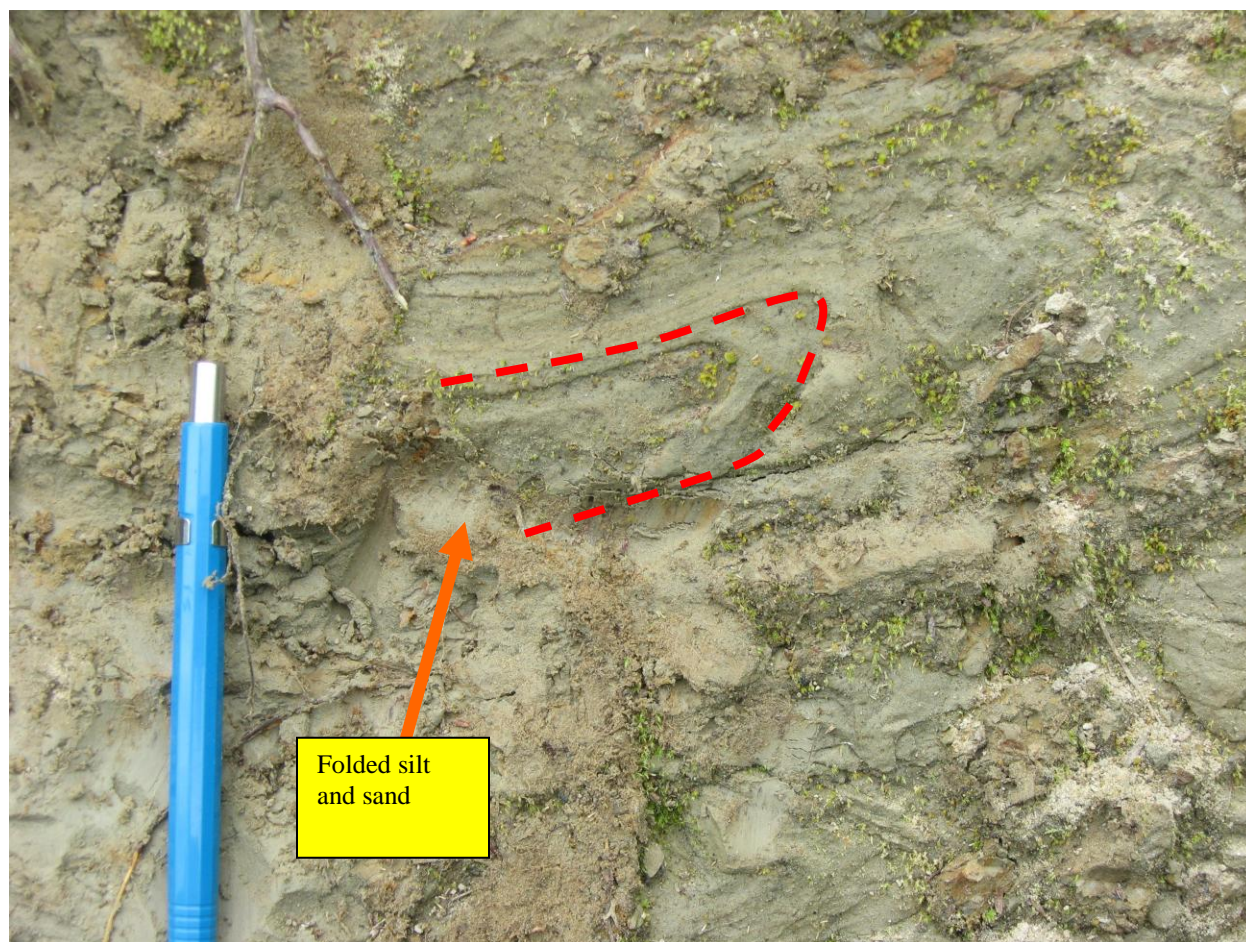


## Appendix 7. Deformational and Liquefaction Features of Quaternary Deposits in the Carnation 7.5-Minute Quadrangle.

Sites are located on Plate 1 of Dragovich and others (2010). Also see unit Qtz in Dragovich and others (2010). Appendix 8 (this study) supplies information on the faults near the critical sites discussed below. Unfortunately due to the quality of the outcrops, dense vegetation, locally poor lighting conditions, and limited operator photographic skills, not all of the deformational and liquefaction features we observed in the field are presented. The following are a few of the features we observed.

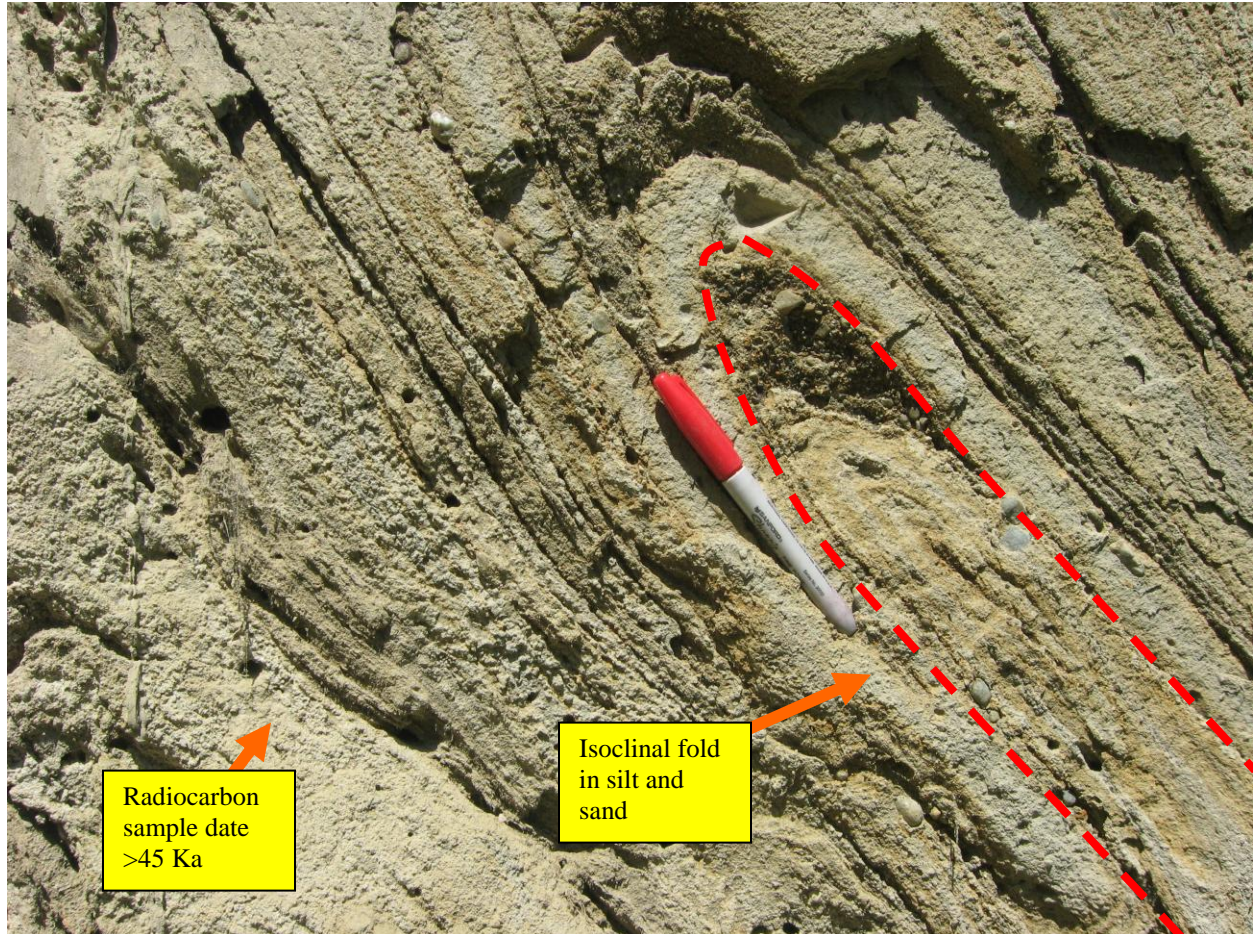


### Figure 1. Critical and Age Site 09-81Z Olympia Beds (unit Qc<sub>0</sub>)

Site 09-4S, Critical Site 09-81Z on Plate 1 of Dragovich and others (2010). Deformed, tilted, folded, laminated to thinly bedded, ancient Snoqualmie River alluvium (unit Qc<sub>0</sub>) in the northernmost part of the Carnation quadrangle. Site is located in the NE $\frac{1}{4}$ NE $\frac{1}{4}$  sec. 18, T26N R7E. We obtained an IRSL age of 47.4  $\pm$  2.76 ka (~47,000 yrs B.P.) at this site. Photo shows folded dense, micaceous silt to silty fine sand and rare sand beds. Note mechanical pencil for scale. There are multiple deformation features at this site, including slickensided fractures, convoluted bedding and rootless folds. Fold shown with dotted red line is likely the result of intense liquefaction. The site also exhibits flames. Other deformational features may be related to the nearby Cherry Valley fault. The overall bedding orientation at a wider scale (outside bounds of the photo) is consistent with the dip of other Qc<sub>0</sub> beds in the area and does show evidence of tectonic tilting. A fracture at this site strikes 350° and dips 66° is sub-parallel to the nearby Cherry Creek fault. The illustrated fold axis trends 190° and plunges 25°. Beds at larger scale strike 114° to 208° and dip 11° to 19° NW.



Photos of Neotectonic and Liquefaction Features  
Carnation 7.5-minute Quadrangle, Washington

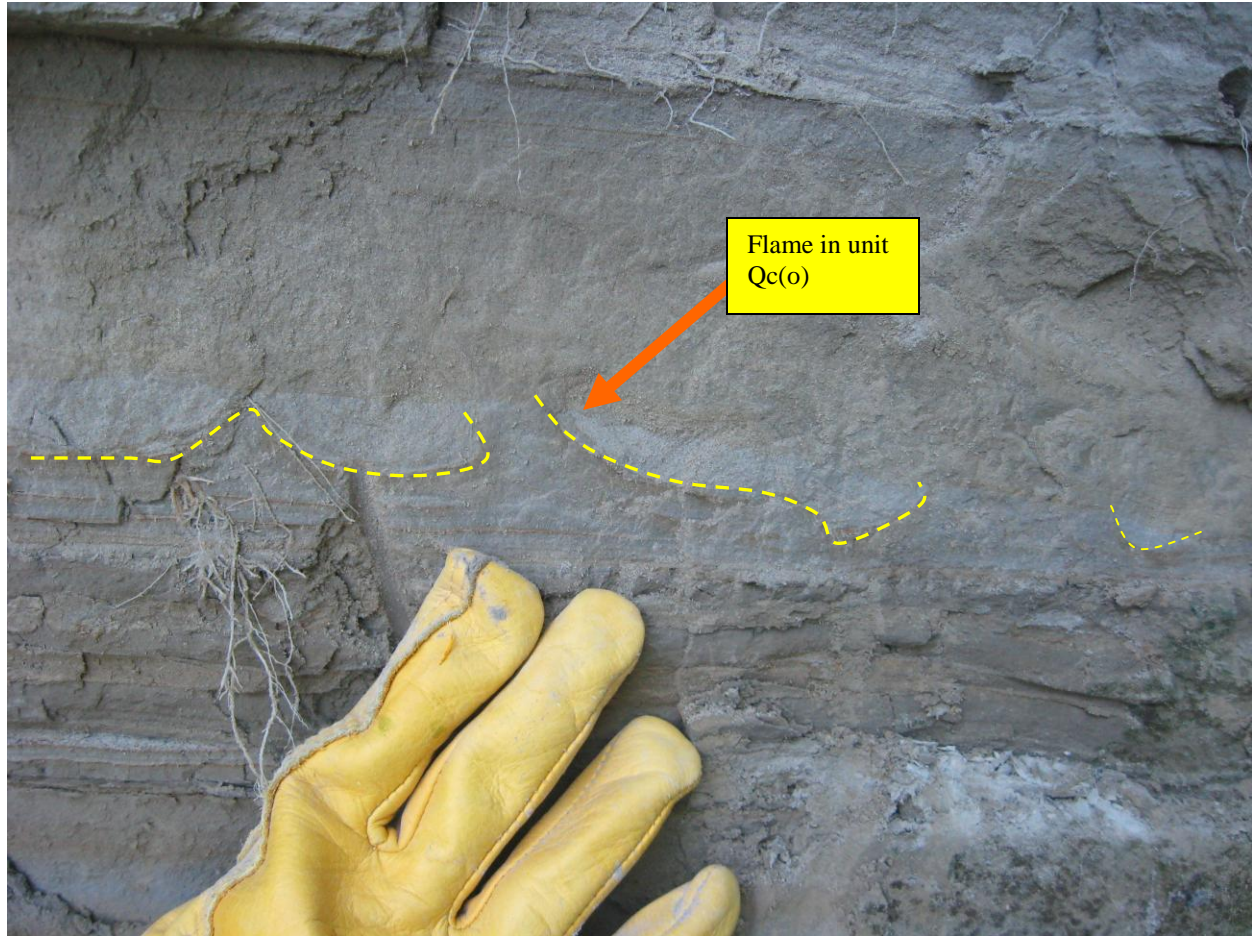


**Figure 2. Age Site 09-14E Olympia Beds (unit Qc<sub>0</sub>)**

Tectonically deformed, tilted, isoclinally folded and thinly laminated to thinly bedded, well stratified ancient Snoqualmie River alluvium (unit Qc<sub>0</sub>) in the southernmost part of the Carnation quadrangle on Plate 1 of Dragovich and others (2010). Outcrop is located in the NW¼NW¼ sec. 21, T25N R7E in MacDonald Park along an access road cut. Radiocarbon site 09-14E (age >45 ka) of Dragovich and others (2010), although two nearby finite ages indicate that the host deposits here are Olympia beds (~26-28 ka). The photos show compact ancient Snoqualmie River overbank deposits that vary from micaceous silt to silty fine sand. Some sediment contains scattered gravel. Fingers of silty sand with some gravel (diamict) invade parts of the outcrop. This diamict appears to be the result of mixing during liquefaction. Note pen for scale. The degree and extent of liquefaction of this large exposure suggests a diapir that intruded the Olympia beds. The ‘infinite’ wood fragment near this photo suggests the diapir originated in older Snoqualmie provenance strata such as unit Qc<sub>pt</sub> (see Dragovich and others, 2010, Cross Section B). The dashed red line shows an isoclinal rootless fold within this diapir. The axis of the fold trends 345° and plunges 55°. There are multiple deformational features in this large outcrop including slickensided fractures and tilted bedding. The fracturing may be the result of deformation along Snoqualmie Valley fault no. 2 (SVF-2). Nearby bedding orientations are S310° D66°NE and S311° D63°NE—with tilting likely the result of compression along the Tolt Hill growth fold of Dragovich and others (2010). We thus interpret the deformational features at this site to be a complex interplay between deformation along SVF-2, liquefaction and broad folding. These sediments are exceptionally thick ancient Snoqualmie River alluvium that is now elevated, folded, and faulted within the Rattlesnake Mountain fault zone. Noteworthy is the degree of deformation and liquefaction in beds as young as 26 ka. This style of deformation extends along the eastern foot of Tolt Hill sub-parallel to SVF-2.



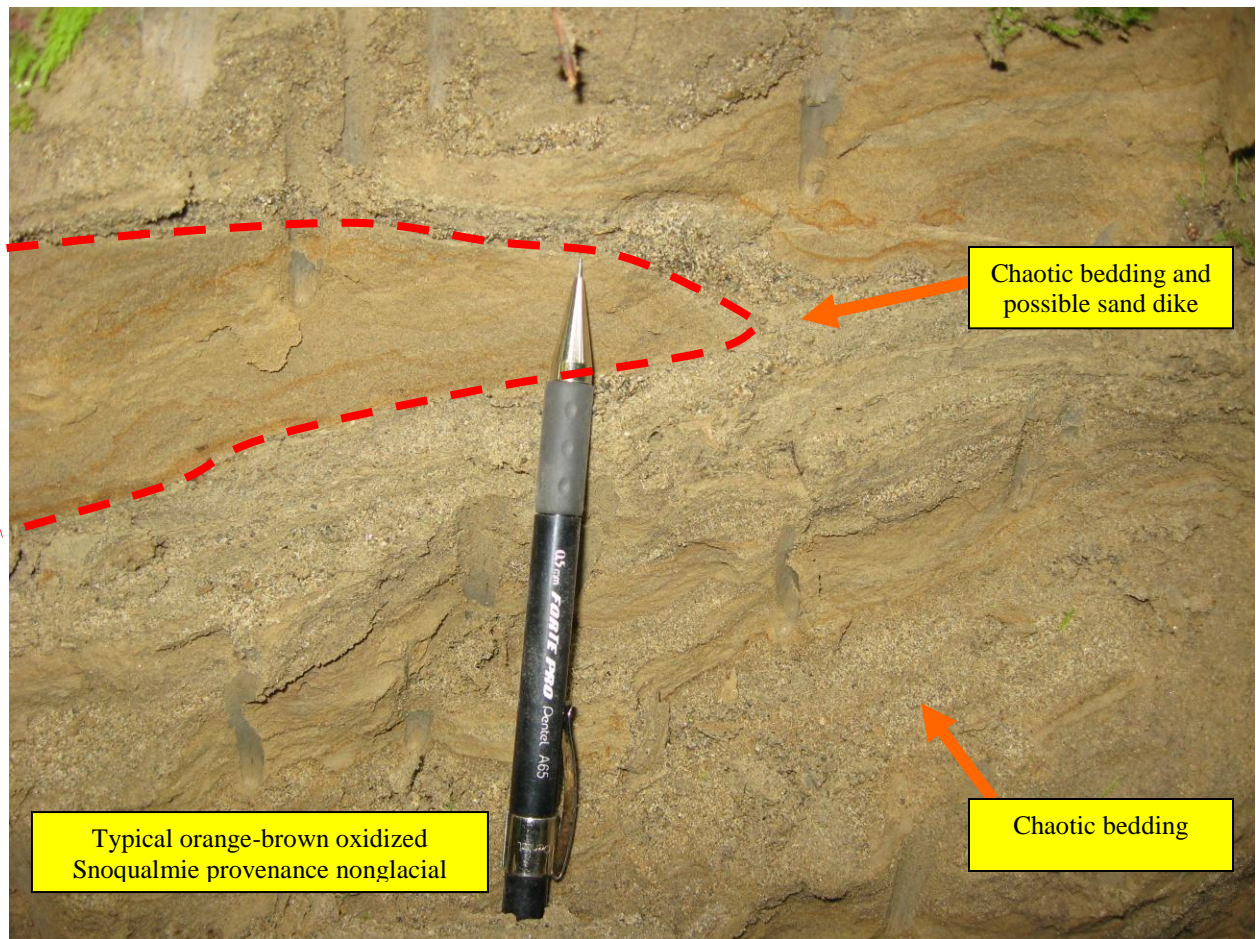
Photos of Neotectonic and Liquefaction Features  
Carnation 7.5-minute Quadrangle, Washington



**Figure 3. Site 09-14H Olympia Beds (unit Qc<sub>o</sub>)**

Tectonically deformed and homoclinally bedded silt and sand in the south-central part of the Carnation quadrangle. Critical site 14H on Plate 1 of Dragovich and others (2010). Site is located in MacDonald Park in the NW¼NW¼ sec. 21, T25N R7E. Liquefaction structures such as this sand dike and flames may have been due to the nearby fault. See also age and deformation information at site 09-14E (above) south of this site. Dashed yellow line shows flames disrupting thinly laminated, micaceous silt to silty fine sand. Note glove for scale. Sand dikes also occur in this ancient overbank deposit near the photo. Bedding here is oriented S208° D11°NE. These sediments are exceptionally thick ancient Snoqualmie River alluvium that is now elevated, folded, and faulted within the Rattlesnake Mountain fault zone.

Photos of Neotectonic and Liquefaction Features  
Carnation 7.5-minute Quadrangle, Washington

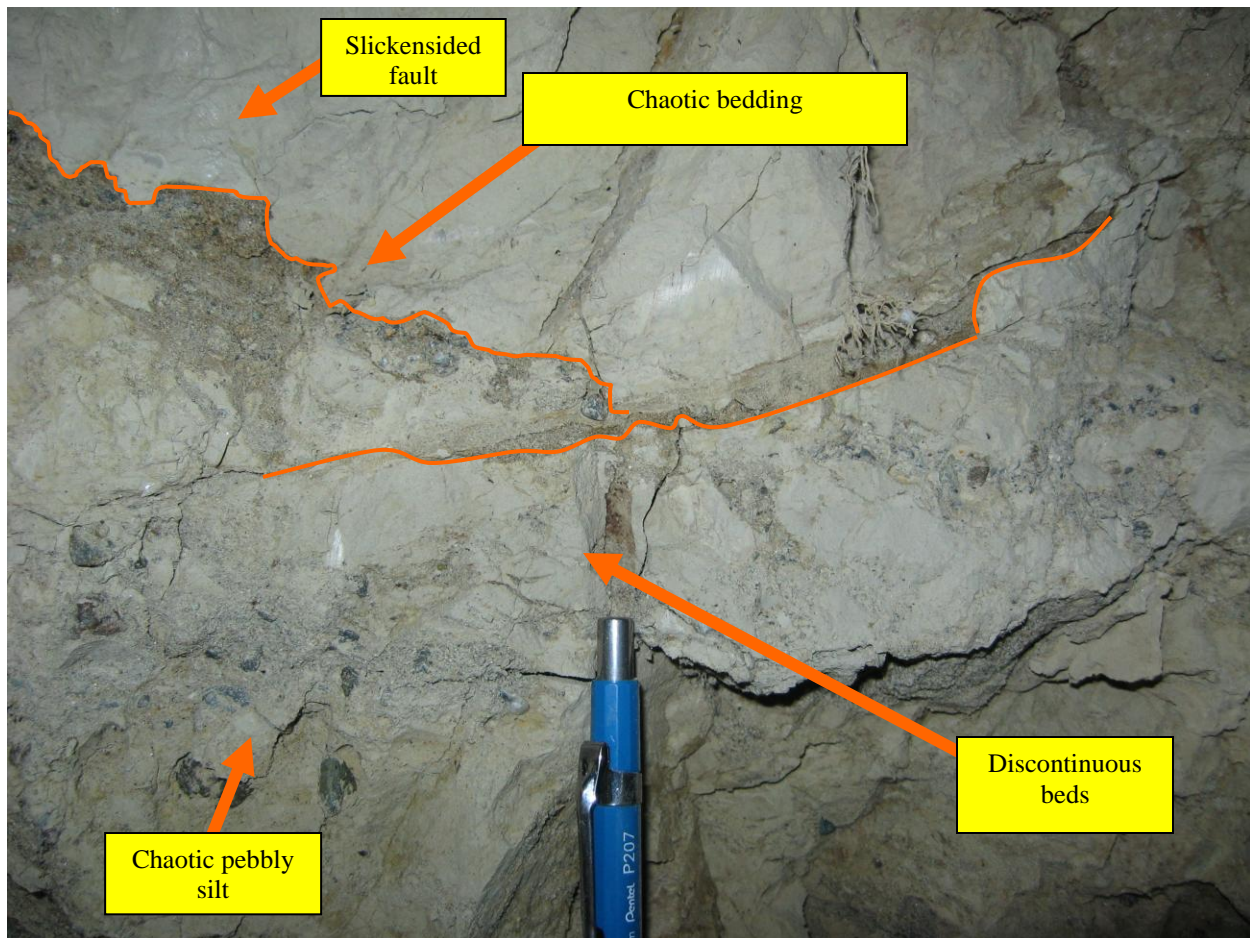


**Figure 4. Site 09-53B Pre-Fraser Ancient Snoqualmie River Alluvium (unit Qc<sub>pt</sub>)**

Tectonically deformed, tilted, isoclinally folded and thinly laminated to thinly bedded ancient Snoqualmie River alluvium (unit Qc<sub>pt</sub>) in the southwesternmost part of the Carnation quadrangle (critical site 53D on Plate 1 of Dragovich and others, 2010). This large roadcut is located in the SW $\frac{1}{4}$ NW $\frac{1}{4}$  sec. 30, T25N R7E along Ames Lake Road. Site is adjacent to Rattlesnake Mountain fault no. 5 of Dragovich and others (2010). Photo shows folded compact, dense, chaotic, silt and micaceous fine sand to medium sand and scattered pebbles with liquefaction features. Note mechanical pencil for scale. A nearby sand dike is oriented roughly north-south (S170° D56°W). Some beds are isoclinally folded as a result of liquefaction near this site. Bedding measured along Ames Lake Road is likely tilted as a result of Quaternary folding as shown on Dragovich and others (2010) and varies from S171° D16°W, S146° D32°SW and S169° D29°SW. Small faults displace ancient Snoqualmie River strata in some outcrops along Ames Road and along with the distinct liquefaction suggest the presence of a larger fault. Fault and fracture orientations are variable. Although not as well exposed, the liquefaction and deformation evident in unit Qc<sub>pt</sub> does not appear to extend into the overlying Vashon advance outwash and lake deposits exposed along Ames Lake Road directly north of this site.



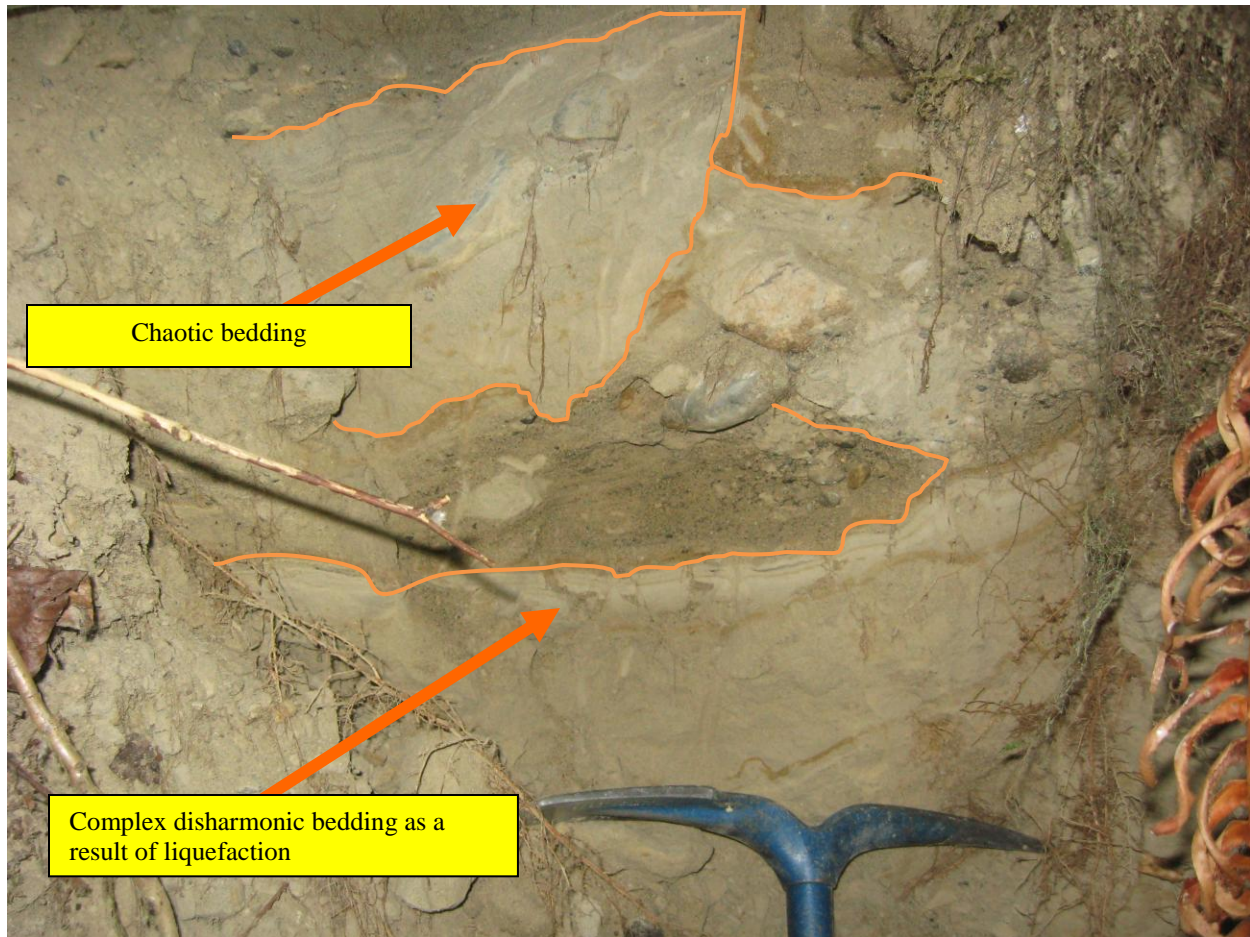
Photos of Neotectonic and Liquefaction Features  
Carnation 7.5-minute Quadrangle, Washington



**Figure 5. Site 09-24N Double Bluff glacial drift (unit Qgd(d))**

Tectonically deformed and liquefied glacial drift in the westernmost part of the Carnation quadrangle. Critical site 24N of Dragovich and others (2010). Site is located in the NE¼ SE¼ sec. 35, T26N R6E near Rattlesnake Mountain fault no. 1 (RMF-1). Photo shows chaotic bedding in dense sand to silty sand with scattered pebbles. Note mechanical pencil for scale. Deformed beds are shown with orange line. There are multiple deformation features present here, including faults, sheared bedding, sand dikes, and other liquefaction features including a large bulbous body of sand and gravel that might be a large injection feature. Some pebbly sand dikes contain included fragments of glacial silt. Dikes and other injection features cross-cut bedding. Several faults were noted in this outcrop. Some faults exhibit slickensides and form discrete discontinuities between disparate beds. Some bedding is sub-vertical near the faults. Faults are generally sub-vertical and parallel RMF-1 (S160° D90°).

Photos of Neotectonic and Liquefaction Features  
Carnation 7.5-minute Quadrangle, Washington

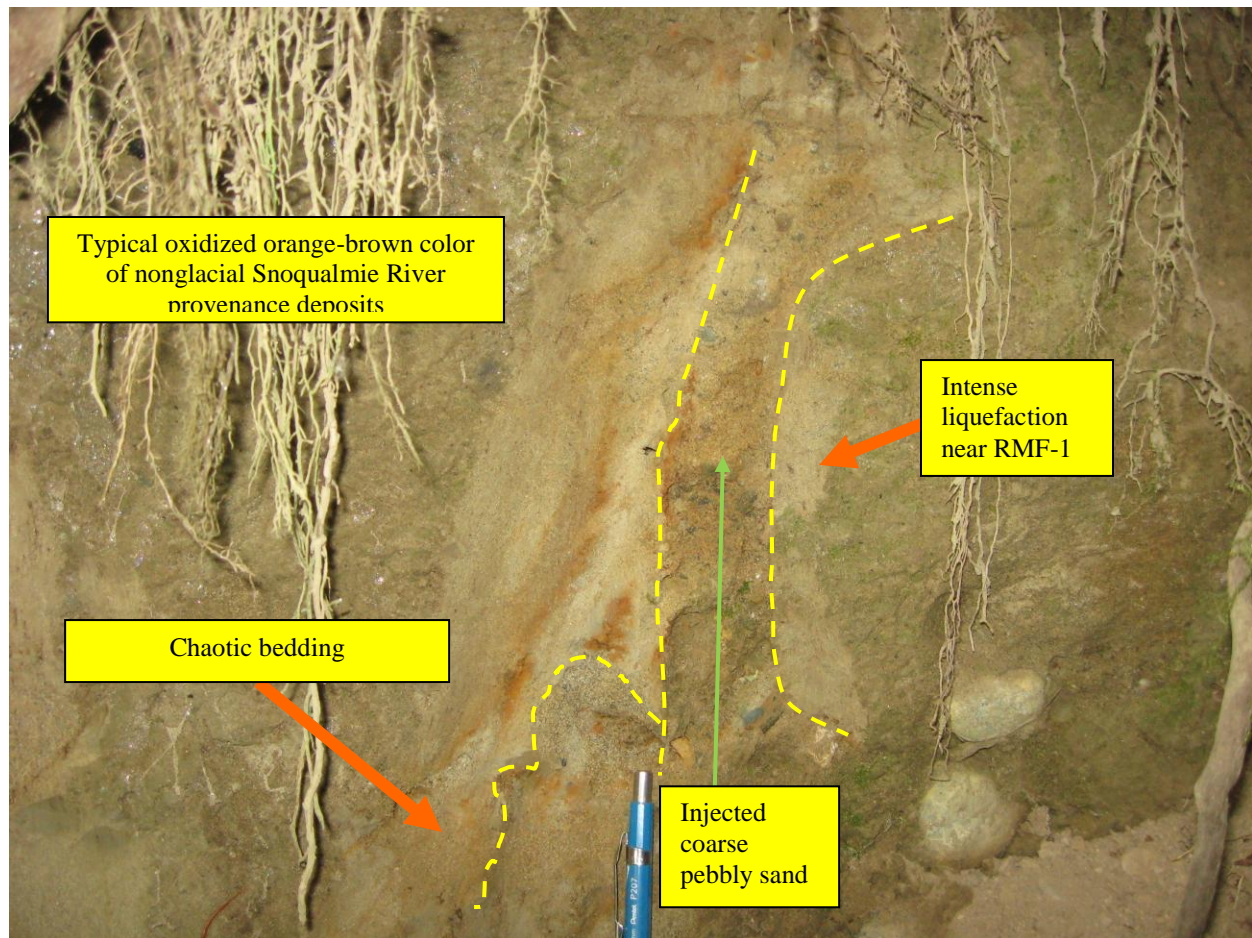


**Figure 6. Site 09-25A Whidbey Formation Snoqualmie River provenance (unit Qc<sub>ws</sub>)**

Critical Site 09-25A on Plate 1 of Dragovich and others (2010). Tectonically deformed and folded nonglacial Whidbey Formation silts and sands with some gravel beds in the westernmost part of the Carnation quadrangle. Site is located in the NE $\frac{1}{4}$ SE $\frac{1}{4}$  sec. 35, T26N R6E and near radiocarbon site 09-25C-1 (age >43 ka; detailed radiocarbon date information and a compilation of radiocarbon age information around the quadrangle are provided in the Appendix 1). Tectonic deformation may be associated with the nearby Rattlesnake Mountain Fault no. 1. Photo shows complex disharmonic beds as a result of liquefaction and folded dense, thin to thickly bedded, micaceous fine sand to medium sand. Note geo pick for scale. Deformed beds are shown with solid orange line (dashed where inferred). Multiple liquefaction features, including fractures, sand dikes, and disharmonic bedding are present at this location. For example, dikes of pebbly sand intrude the deposits near this site. See also site 25A #2 below. These sediments are exceptionally thick ancient nonglacial Whidbey Formation that is now elevated, folded, and faulted within the Rattlesnake Mountain fault zone.



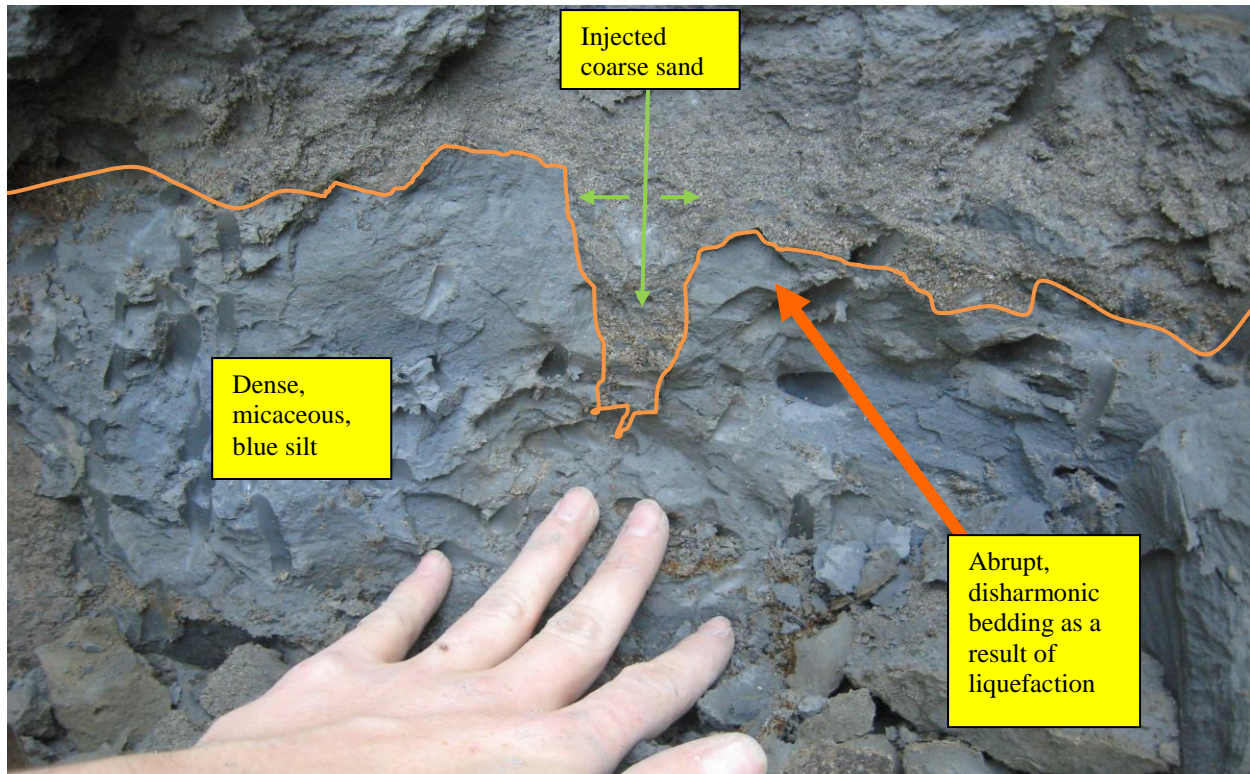
Photos of Neotectonic and Liquefaction Features  
Carnation 7.5-minute Quadrangle, Washington



**Figure 7. Site 09-25A (#2) Whidbey Formation, Snoqualmie River provenance (unit Q<sub>cws</sub>)**

Critical Site 25A on Plate 1 of Dragovich and others (2010). Also see site 25A above. Deformed silts and sands in the southernmost part of the Carnation quadrangle. Site is located in the NE $\frac{1}{4}$ SE $\frac{1}{4}$  sec. 35, T26N R6E and near radiocarbon site 09-25C (age >43Ka; Appendix 1). Deformation may be associated with the nearby Rattlesnake Mountain Fault no. 1. Photo shows pebbly sand dike of thin to thickly bedded, micaceous fine to medium sand. Note mechanical pencil for scale. Deformed beds are shown with solid orange line and possible injectite is shown bounded with yellow dashed lines with green arrow showing possible injection direction. The injectite may contain fragments of the underlying glacial deposits (unit Qgd<sub>4</sub>). Multiple liquefaction features including fractures, sand dikes, and disharmonic bedding present at this location. These sediments are exceptionally thick ancient Whidbey Formation that is now elevated, folded, and faulted within the Rattlesnake Mountain fault zone.

Photos of Neotectonic and Liquefaction Features  
Carnation 7.5-minute Quadrangle, Washington

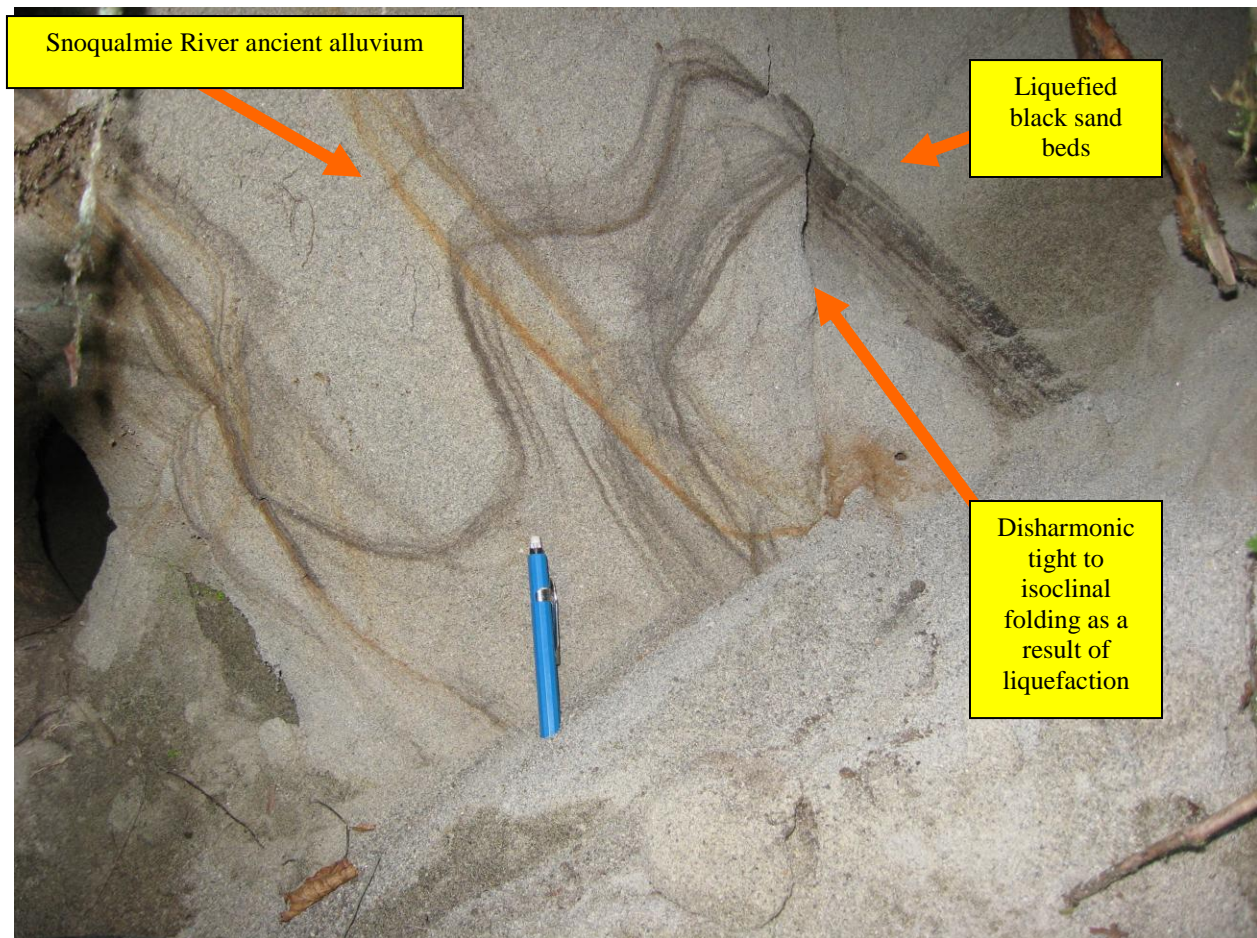


**Figure 8. Site 09-43H Pre-Fraser ancient Snoqualmie River Alluvium (unit  $Qc_{pf}$ )**

Critical site 09-43H on Plate 1 of Dragovich and others (2010). Deformed ancient Snoqualmie River alluvium (unit  $Qc_{pf}$ ) in the northernmost part of the Carnation quadrangle. See also Figures 11, 12 and 13. Site is on the steep slopes above Cherry Creek in the SW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 16, T26N R7E where several large outcrops were discovered. Deformation may be associated with the nearby Cherry Valley Fault; however, we recognize that these features may also have formed as disturbance associated with earthquakes having foci well outside the study area. Photo shows dense, micaceous, blue silt that has been fractured and injected by sands, possibly due to lateral spreading. Note hand for scale. The contact between the sand and the silt is shown with an orange line, and green arrows show possible spreading and injection. There are multiple deformation features, including folds, injectites, fractures, faults, and slickensides in this ancient overbank deposit. Wider-scale measurements on the attitude of the bedding documented strikes between 165° to 182° and dips from 85° to 15°W. A fault at this site has a strike of 135° and dips 90. Site is located near radiocarbon site 09-43G (age >44 ka). Detailed radiocarbon date information and a compilation of radiocarbon age information around the quadrangle are provided in Appendix 1. We obtained an IRSL age of 48 ka on similar ancient Snoqualmie River alluvium west of Cherry Creek fault. Because those deposits are on the opposite side of the Cherry Creek fault we map these deposits more conservatively as pre-Fraser in age.



Photos of Neotectonic and Liquefaction Features  
Carnation 7.5-minute Quadrangle, Washington

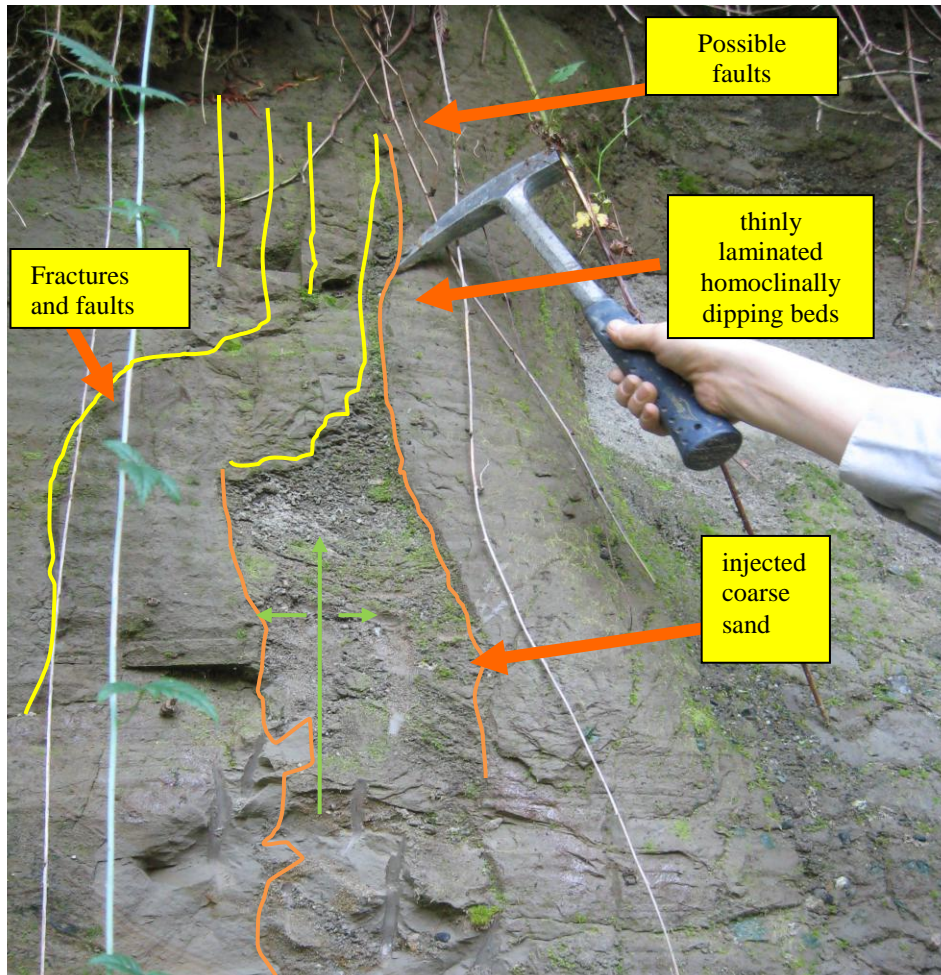


**Figure 9. Site 09-43H (#2) Ancient Snoqualmie River Alluvium (unit Qc<sub>pt</sub>)**

Critical Site 09-43H on Plate 1 of Dragovich and others (2010). Deformed ancient Snoqualmie River alluvium (unit Qc<sub>pt</sub>) in the northern part of the Carnation quadrangle. See also Figures 10, 12 and 13 for more information on this site. Site is located near Cherry Creek in the SW¼ NW¼ sec. 16, T26N R7E and near radiocarbon site 09-43G (age >44 ka; Appendix 1). Deformation may be associated with the proximal Cherry Valley fault. Photo shows dense, micaceous, sand that has been liquefied and distorted or folded. Note the black sand layers (dotted orange lines) and mechanical pencil for scale. The brown “layer” is an oxidation front and not bedding. There are multiple deformation features, including folds, injected strata, fractures, faults, and slickensides in these ancient overbank deposits near this site. Bedding in deposits strike between 165° to 182° and dip 85°SW to 15°SW. A fault at this site has a strike of 135° and dips 90°.



Photos of Neotectonic and Liquefaction Features  
Carnation 7.5-minute Quadrangle, Washington

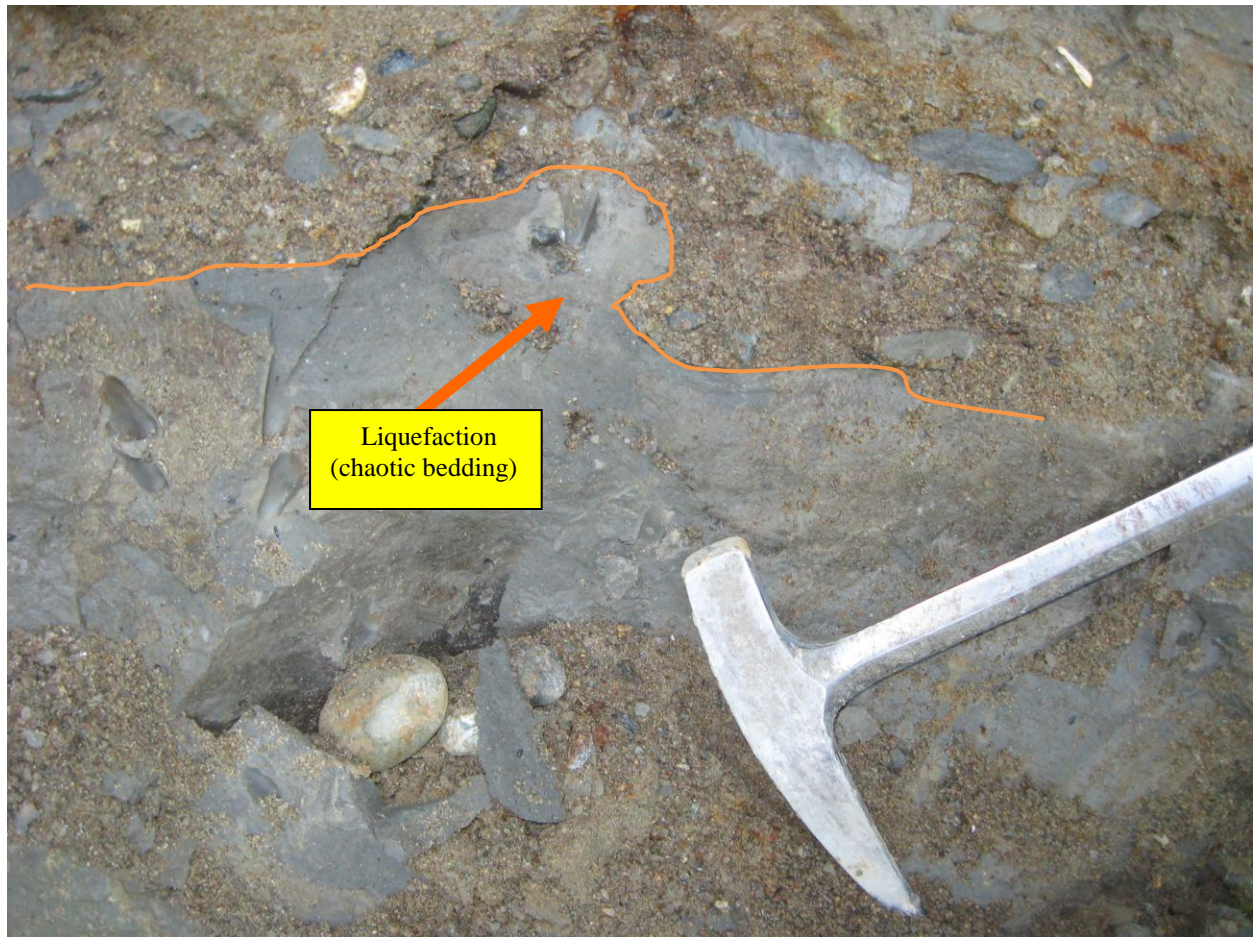


**Figure 10. Site 09-43H (#3) Pre-Fraser ancient Snoqualmie River Alluvium (unit Qc<sub>pt</sub>)**

Critical Site 09-43H on Plate 1 of Dragovich and others (2010). Deformed ancient Snoqualmie River alluvium in the northernmost part of the Carnation quadrangle near Cherry Creek (SW¼ NW¼ sec. 16, T26N R7E); also near radiocarbon site 09-43G (age >44 ka; Appendix 1). Deformation may be associated with the Cherry Valley Fault. Photo shows dense, thinly laminated, micaceous grey silt that has been injected with a coarser pebbly sand bed. Injection may have accompanied lateral spreading when ancient Snoqualmie River alluvium was deposited in this area. Note rock hammer for scale. The contact between the coarse sand and the silt is shown with an orange line; possible faults are shown with yellow lines (dashed where inferred), and arrows indicate possible spreading and injection. There are multiple deformation features, including folds, injected strata, fractures, faults and slickensides in this overbank deposit around this site. Bedding in the wider scale strikes between 165° to 182° and dips 85° to 15°SW. A fault at this site has a strike of 135° and dips 90°. These sediments are exceptionally thick ancient Snoqualmie River alluvium that is now elevated, folded, and faulted near the Cherry Valley Fault Zone. See also Figures 10, 11 and 13 for more information on this site.



Photos of Neotectonic and Liquefaction Features  
Carnation 7.5-minute Quadrangle, Washington

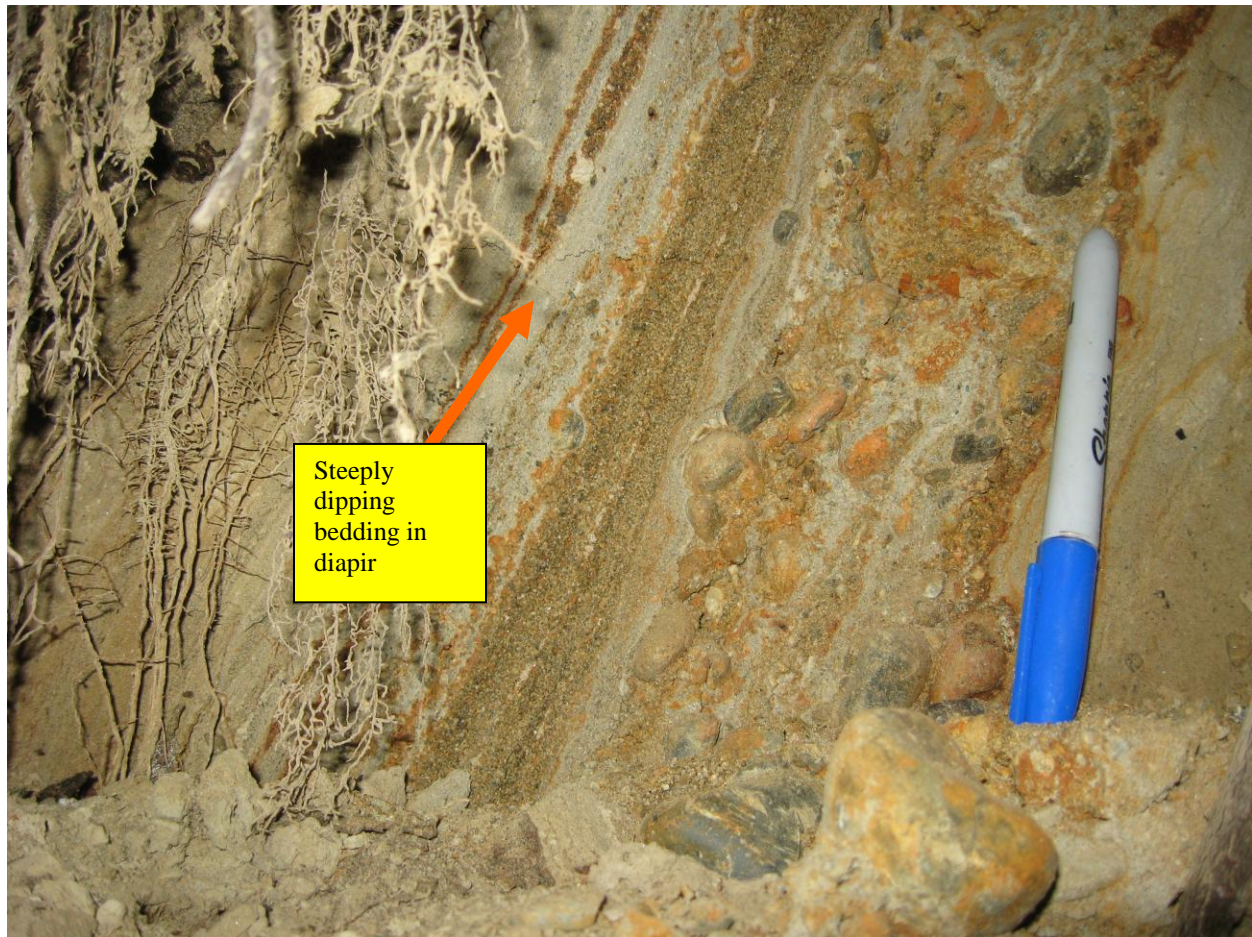


**Figure 11. Site 09-43H (#4) Ancient Snoqualmie River Alluvium (unit  $Q_{c_{pf}}$ )**

Tectonically deformed, tilted, folded, and well stratified, thick ancient Snoqualmie River alluvium (unit  $Q_{c_{pf}}$ ) in the northernmost part of the Carnation quadrangle. Critical site 43GH on Plate 1 of Dragovich and others (2010). Site is located near Cherry Creek in the SW¼ NW¼ sec. 16, T26N R7E. Photo shows dense, micaceous, blue silt interbedded with pebbly sand. The sand is chaotically bedded with the silts and is locally injected into the silt. Note rock hammer for scale. The contact between the coarse sand and the silt is shown with an orange line. There are multiple deformation features, including folds, injected features, fractures, faults, and slickensides, in this ancient overbank deposit at this site. See Figures 10-12 for more information on this site.



Photos of Neotectonic and Liquefaction Features  
Carnation 7.5-minute Quadrangle, Washington



**Figure 12. Site 09-45P Olympia Beds (unit Qc<sub>0</sub>)**

Subvertical beds in the southernmost part of the Carnation quadrangle. Critical site 45P on Plate 1 of Dragovich and others (2010). Site is located in the NW¼NW¼ sec. 21, T25N R7E in MacDonald Park. Photo shows thinly laminated, micaceous silt to silty fine sand that is steeply dipping. Steeply dipping strata shown in the photo are part of a large isoclinally folded diapir near Snoqualmie Valley fault no. 2. The diapir contains steep bedding and a few rootless isoclinal folds; host strata are less deformed. There are multiple deformation features, including flames and sand dikes, in this ancient overbank deposit near this site. Bedding measured S276° D45-90°N in the diapir to S28 D26SE in less disturbed host strata. These sediments are exceptionally thick ancient Snoqualmie River alluvium that is now elevated, folded, and faulted within the Rattlesnake Mountain fault zone. Quaternary deformation at this site, as well as other geophysical, geomorphic, and lithologic anomalies, suggests that the Carnation area may be seismically active.