1Sep20

**Supplemental Files for:**

**Minimal stratigraphic evidence for coseismic coastal subsidence during 2000 years of megathrust earthquakes at the central Cascadia subduction zone**

**by Nelson, Hawkes, Sawai, Horton, Witter, Bradley, and Cahill**

**Introduction**

The Supplemental Files for this paper include the following detailed information and data for sites described in the paper that are not summarized elsewhere. Except for the series of pdf files that make up Fig. S1, the figures included in the Supplemental Files are in one pdf file, readable with Adobe Reader 9 and higher, but the captions for those figures are listed below (Part 1). Fig. S1 consists of ten separate pdf files of overlapping imagery showing core and sampling locations in detail; Table S1 (Part 2, below) is a key to the field labels and UTM coordinates for these cores and sampling locations, and to their labels on Fig. 4 and the ten pdfs of Fig. S1 (S1A through S1I). The three tables of micropaleontologic data (Part 2, below) are separate Excel files. Summaries of previous investigations, the tidal marsh setting of our study site, and methods of measuring sampling elevations are included in Part 3 (In this section, figure numbers without an “S” reference figures in the published paper.). The explanation of variance added to radiocarbon age errors (Part 4), and the listing of code for selected OxCal radiocarbon age models (Part 5) also appear in this text file. References cited in captions for the supplemental figures, the Excel tables, and elsewhere in this file are listed under References Cited at the end of the file.

**Supplemental files**

**Part 1 -** **Captions for** **Supplemental File figures**

(the figures are included as separate pdf files without captions)

**Figs. S1index, S1A through S1I.** Air photograph imagery showing locations of gouge cores (described in the field), vibracores (Sa, Sb, Ka, Kb), and samples collected on Cox Island, along Deming Creek in South Inlet, and in a marsh along the North Fork of the Siuslaw River (Fig. 2). Labels on the imagery are the original field numbers for cores and outcrops; how the original numbers correspond with the consecutive core numbers used on Fig. 4 are listed in Table S1 (Excel file). Locations are color coded by investigators and years of collection as shown on each figure. Initial cores on Cox Island and all cores in South Inlet were described in 1987-1990 (green dots). Later cores and samples, described and(or) collected in 2005-2008, are shown by dots of other colors. As in 1987-1990, locations in 2005-2008 were made by marking positions with pin holes on greatly enlarged air photographs (1:1500 to 1:2500 scale). Although 2007–2008 locations were also measured using a handheld GPS unit, many 2007–2008 GPS locations had systematic errors. Imagery from Oregon Explorer in 2009 (<http://oregonexplorer.info/topics/imagery?ptopic=98>).

Fig. S1index. - Index to the areal coverage of more detailed imagery sheets (below).

Fig. S1A (sheet A) – northeastern Cox Island

Fig. S1B (sheet B) – eastern Cox Island

Fig. S1C (sheet C) – western Cox Island

Fig. S1D (sheet D) – northwestern Cox Island

Fig. S1E (sheet E) – southeastern Cox Island

Fig. S1F (sheet F) – northeastern Cox Island

Fig. S1G (sheet G) – southwestern Cox Island

Fig. S1H (sheet H) – South Inlet

(two short lines labeled 1 and 2 in the southern part of sheet H mark the modern foraminiferal and diatom transects of Nelson and Kashima, 1993)

Fig. S1I (sheet I) – North Fork of the Siuslaw River

**Fig. S2.** Simplified lithologies, probable stratigraphic unit contact correlations (dashed lines), and 14C ages (ka, midpoint of laboratory-reported age; times 1000 14C yr BP) for six reconnaissance 25-mm-diameter gouge cores along a transect across the mouth of Deming Creek in South Inlet, Siuslaw River estuary (latitude 43.965º, longitude -124.055º; modified from Fig. 2 of Nelson, 1992). Location of cores shown by labeled dots on Fig. 2, and more accurately with labeled cores on Fig. S1H. Lithologies described in 1987 using a description system similar to Troels-Smith (1955), as explained in Nelson et al. (1996a, Part 1 of Supplemental Information for that paper). Speculative correlations of a few contacts with those labeled on Fig. 5 are listed with a question mark.

**Fig. S3.** Simplified lithologies, probable stratigraphic unit contact correlations (dashed lines), and 14C ages (ka, midpoint of laboratory-reported age; times 1000 14C yr BP) for three reconnaissance 25-mm-diameter gouge cores along a transect across Deming Creek, northeast of the transect shown on Fig. S2, in South Inlet, Siuslaw River estuary (latitude 43.968º, longitude -124.051º). Location of cores shown by labeled dots on Fig. 2, and more accurately with labeled cores on Fig. S1H. Lithologies described in 1987 using a description system similar to Troels-Smith (1955), as explained in Nelson et al. (1996a, Part 1 of Supplemental Information for that paper). Speculative correlations of a few contacts with those labeled on Fig. 5 are listed with a question mark.

**Fig. S4.** Simplified lithologies and probable stratigraphic unit contact correlations (dashed lines) for six of eight reconnaissance 25-mm-diameter gouge cores along a north-south transect near the mouth of the North Fork of the Siuslaw River (latitude 43.989º, longitude -124.076º). Location of cores shown by labeled dots on Fig. 2, and more accurately with labeled cores on Fig. S1I. Lithologies described in 1987 using a description system similar to Troels-Smith (1955), as explained in Nelson et al. (1996a, Part 1 of Supplemental Information for that paper). Speculative correlations of a few contacts with those labeled on Fig. 5 are listed with a question mark.

**Fig. S5.** An extended version of Fig. 6 showing an additional 5 m of the eastern part of the outcrop not shown in the published paper. Lithologic contacts and peaty units as mapped along 11.5 m of outcrop 1 on the northeast shore of Cox Island (latitude 43.975º, longitude -124.064º) correlated with contacts in cores S and K (Figs. 4 and 5; mapping methods described by Nelson, 2015). Contacts B, Ea, Fa, and H, labeled in the cores, were not identified in the outcrop. Location of 14C ages from the cores and outcrop sediment blocks (Table 2) are shown with Troels-Smith (1955; Nelson, 2015) descriptions of units in a section described from the outcrop; core descriptions are shown in Fig. 5. Lower case letter after minimum or maximum 14C ages (calibrated ages times 1000 yr BP) keys each age to Table 2. Thickness and contact depths in cores S and K corrected for compaction as explained in Fig. 5.

**Fig. S6.** (A) Reconstructed elevation for zones sampled for fossil diatoms in core S near the north edge of Cox Island (Figs. 3 and 6) using a weighted averaging-partial least squares diatom transfer function (e.g., Sawai et al., 2004; Kemp and Telford, 2015) (data in Table S4), as explained in the paper. The approximate gradational boundaries between low marsh, middle and high marsh, and marsh to upland transition zone are based on vascular plant communities on Cox Island studied by Brophy (2009) and by Hawkes et al. (2010). Horizontal bars on black ovals show two standard deviation errors on reconstructed elevations in SWLI units (elevations shown relative to NAVD88 at base). (B) Results of the modern analog technique using dissimilarity coefficients (minimum distance to closest analog, MinDC) to test the degree to which diatom assemblages in the modern samples provide close analogs for the fossil assemblages. Samples with coefficients lower than the 20th percentile are good analogs; samples with coefficients larger than the 20th percentile are poor analogs (e.g., Horton and Edwards, 2006; Kemp and Telford, 2015). Red ovals on both A and B mark the 38 of 136 samples that do not have good analogs in the modern dataset of Sawai et al. (2016).

**Part 2 - Tables** (separate Excel files)

**Table S1.** Key to new and old labels for cores and sampling locations located on Figs. S1A-S1I

**Table S2.** Foraminiferal species abundance, concentration, and reconstructed elevations for samples from core S and outcrop 1

**Table S3.** Total diatom valves counted in (compacted) core S

**Table S4.** Diatom species or genera abundance for most common taxa in core S

**Part 3 – Previous investigations, tidal marsh setting, and sampling elevations**

**Previous investigations**

Along the central Oregon coast, with the exception of two studies of tsunami deposits in freshwater sequences (Peterson et al., 2010) and Graehl et al.’s, (2014) study of tidal stratigraphy at Yaquina Bay, the history of Cascadia’s megathrust has been inferred from decades-old reconnaissance stratigraphy and dating by investigators with differing perspectives on the relative importance of processes of tidal-marsh sedimentation and late Holocene sea-level change (e.g., Darienzo et al., 1994; Long and Shennan, 1994; Nelson and Personius, 1996; Peterson and Darienzo, 1997; Nelson et al., 1998; Long and Shennan, 1998). Only two studies deal specifically with tidal stratigraphy in the estuary of the Siuslaw River: Nelson (1992) and Briggs (1994).

In 1987 and 1990, Nelson, (1992) described 28 gouge cores (100-cm-long segments, 2.5 cm diameter) along transects on Cox Island, in South Inlet, and in a marsh 1.7 km up the North Fork of the Siuslaw River, and examined four outcrops north and south of the main channel of the Siuslaw River near Cox Island (Fig. 2). In describing the stratigraphy Nelson, (1992) used a lithofacies system, similar to that of Troels-Smith (1955), based on the fluvial lithofacies description system of Miall (1978) (explained in the Supplemental Information for Nelson et al., 1996a). Five main lithofacies were modified with 18 lithofacies modifiers and 11 types of macrofossils were noted. Because of the importance of distinguishing sudden from gradually formed stratigraphic contacts, contact thicknesses were grouped into seven classes with sharp (≤3 mm) contacts distinguished from abrupt (≤1 mm) contacts. Nelson (1992) was conservative in his interpretation of contacts: “Transgressive overlap boundaries (TOB; peat-mud contact of Nelson et al., 1996b) and regressive overlap boundaries (ROB; mud-peat contact of Nelson et al., 1996b) do not necessarily indicate sea-level changes because, for example, a ROB may result from rapid aggradation during a period of relative sea-level (RSL) rise. In mid-estuary environments, many TOBs and ROBs reflect local changes in sedimentation rates due to the many highly interrelated factors involved in marsh development, erosion, and(or) burial. Nevertheless, if individual TOBs or ROBs can be correlated for tens to hundreds of meters along transects of cores at a site, they can be used as indicators of changes in the rate of RSL rise relative to the local rate of sedimentation or marsh accretion. Only where radiocarbon dating shows many overlap boundaries at widely spaced sites to be synchronous can regionally significant positive and negative tendencies of RSL movement be identified.” (Nelson (1992, p. 293, references in original removed from this quote).

Nelson, (1992) focused his summary of reconnaissance investigations on two core transects across the marshes along Deming Creek in a small inlet on the northeast side of South Inlet (Figs. 2, 3, and S1, S2, S3, and Table S1 in Supplementary files). Both transects show 2- to 3-m-thick sequences of peaty sediment, most of it reddish-brown (5YR to 7.5YR color hues), high-marsh peat with coarse fibrous textures, dating from the past 2000 years. Most of the contacts between stratigraphic units in the cores are gradational except those of sand beds near the center of the inlet. Nelson (1992) interpreted these sequences as recording gradual changes in RSL smaller than the vertical range of high-marsh environments (<0.7 m), most probably <0.5 m. Similarly, in a transect of 8 cores in a marsh 1.3 km up the North Fork of the Siuslaw River (Figs. 2, S1I, and S4), Nelson (1992) noted mostly peat and peaty mud in the upper 4–7 m of sediment; along a 10-core transect on Cox Island (transect A, Fig. 4), and in two gouge cores in a marsh 2.7 km northeast of Cox Island, peat was also the dominant lithology in 4-m-thick sequences of interbedded peat, muddy peat, and peaty mud. Four 1.5-m-high outcrops between the mouth of the North Fork and 3 km up the Siuslaw River along its north side showed mostly peat with very gradational contacts. At the outcrop across the river from Cox Island (Fig. 2), the upper of two 2- to 4-cm-thick sand beds in 1.5 m of peat and muddy peat may correlate with the sand bed at contact A on Cox Island (discussed below). Large spruce stumps on the river bank here and 0.5–2 km upriver are rooted below the base of the outcrops. Based on the prevalence of peaty sediment and gradational contacts between stratigraphic units at these sites, Nelson (1992) concluded that changes in RSL marked by peat-mud and mud-peat contacts were mostly gradational and probably <0.5 m. Large (>1 m), regional changes in RSL, as postulated about that time to have been caused by subsidence during great earthquakes in northern California, northern Oregon, and southern Washington (e.g., Darienzo and Peterson, 1990; Darienzo et al., 1994; Hemphill-Haley, 1995; Atwater and Hemphill-Haley, 1997), were apparently precluded, at least for the past 2000 years in this part of the Siuslaw River estuary (Nelson, 1992; Atwater et al., 1995; Atwater and Hemphill-Haley, 1997, p. 79).

Briggs (1994) described 17 25-mm-diameter gouge cores and four 70-mm-diameter pound cores from 10 sites in the Siuslaw River estuary 4–24 km upriver from the sea. The larger diameter cores consisted of aluminum pipe manually pounded <3 m into tidal sediment. One to four cores at each site were described using six lithologies (similar to the simplified lithologies of Fig. 5) and two thicknesses of stratigraphic contacts (sharp, <5 mm; gradational, >5 mm), making the type of environmental changes recorded by the small number of cores at each site difficult to interpret. Diatom assemblages from 20 samples in two cores were scanned for “marine/brackish” diatoms by comparing them with diatoms in six control assemblages (19 total species in 11 genera) from modern environments at three Oregon estuaries. Seven 14C ages were obtained on 100-mm-thick bulk peat samples from three of the larger diameter cores.

Like Nelson (1992), Briggs (1994) interpreted the stratigraphy in his seven cores within 5 km of Cox Island as recording gradual RSL changes rather than sudden land-level changes during megathrust earthquakes. His single gouge core from the center of Cox Island showed lithologies similar to those in our nearest core (19 on Fig. 4), about 200 m to the northeast, but no sharp contacts (Our contact A was probably in the middle 0.3 m of his core, which was not recovered.). Four cores taken by Briggs (1994) along Deming Creek in South Inlet within 200 m of Nelson’s (1992) cores showed similar lithologies. Calibrated 14C ages on bulk peat from a 3.25-m-long pound core collected between the two core transects of Nelson (1992)(Fig. 2) are 273–10 cal yr BP (0.8 m depth) and 2034–1632 cal yr BP (3.2 m depth) (laboratory reported ages listed in Briggs, 1994, p. 46). Samples from the upper 2 m of the pound core showed entirely fresh diatom assemblages above 1 m, and low numbers of marine/brackish species from 1–2 m (Briggs, 1994, p. 48). Briggs (1994, p. 37) inferred that the continuity of peat in the pound core and the peat and muddy peat with gradational contacts in the other three cores reflected gradual submergence over the past 2000 years. He also suggested that a 3- to 5-cm-thick clean fine sand bed in two of the cores (2.7 m and 3.7 m depths) may have been deposited by a tsunami. In two 4-m-long cores taken on the west side of the North Fork of the Siuslaw River between our core transect shown on Fig. 2 and the mouth of the river, Briggs (1994) found continuous peat in one and alternating beds of mud and peat in the other. He suggested the latter stratigraphy recorded changes in the position of river channels rather than sudden changes in RSL during earthquakes.

In contrast, Briggs (1994, p. 145) attributed alternating beds of peaty, muddy, and occasionally sandy sediment in cores at sites 4–18 km upriver from Cox Island, to sudden subsidence during 1– 5 megathrust earthquakes. For example, four cores at a site 10 km from the sea (4 km upriver from Cox Island) with alternating beds of mud, peaty mud, and muddy peat were interpreted as probably recording subsidence during 2–3 megathrust earthquakes despite the fact that only 5 of 19 upper contacts on peaty units in the four cores were described as sharp (<5 mm). At the site with the most detailed record, 12 km from the sea, five peat units below sharp contacts in a pound core were dated at 665–489 cal yr BP, 1340–1082 cal yr BP, 1560–1305 cal yr BP, 1524–1273 cal yr BP, 2034–1632 cal yr BP, respectively with depth. But the stratigraphy in the two gouge cores at this site was inferred to record only three coseismic subsidence events and all upper contacts on peaty units were gradational (Briggs, 1994, p. 42–43). Scanning for marine/brackish diatoms in 10 samples from the pound core showed insufficient variation in diatom assemblages to suggest significant changes in tide levels, except across the third contact in the pound core (Briggs, 1994, p. 48–49, 150). With only reconnaissance descriptions of such a small number of cores of variable stratigraphy from each site, interpretation of sudden RSL changes from core stratigraphy is problematic. The sharp contacts in the upper 0.5–1 m of a third of Briggs’ (1994) cores upriver from Cox Island, two of which are overlain by sand beds, may correlate with our contact A on Cox Island (Fig. 5). However, the extent to which the stratigraphic changes in these upriver cores are primarily the result of river processes, such as channel migration during floods or silt aggradation following landslides in the drainage basin—rather than sudden earthquake-induced RSL changes—cannot be determined from so few cores (e.g., Nelson, 1992; Nelson et al., 1996b; Shennan et al., 2016; Nelson et al., 2020).

**Tidal marsh setting**

Tidal marshes, like those that cap stratigraphic evidence of regional coseismic subsidence and tsunami deposition at other Cascadia estuaries, line parts of the lower reaches of the Siuslaw River and the North Fork of the Siuslaw River, 0.5–4 km east of a field of north-south-trending sand dunes on the east edge of Florence (Fig. 2). In the early nineteenth century the present fringing high marshes in the lower reaches of the Siuslaw River and the North Fork of the Siuslaw River were probably covered by tidal swamps with abundant Sitka spruce (*Picea sitchensis)*(Hawes et al., 2002; Brophy, 2009). But since the fire of 1846 and increasing land disturbance through logging and grazing⎯from the late nineteenth century into the middle twentieth century⎯most of the sites have been covered with tidal marsh (Hoffnagle, 1979; Hennessy, 2005). The expansion of low and middle marsh on central and western Cox Island, inferred from early twentieth century maps (Hoffnagle, 1979; Frenkel and Boss, 1988), may be the result of minimal drainage and diking for grazing combined with sediment aggradation caused by piling installation along channels around much of the island and placement of dredge spoil along its north shore (Hennessy, 2005).

Although Hoffnagle (1979) noted that most of the vegetation of Cox Island could be classified (following Jefferson, 1975) as immature high salt marsh, he described nine distinct plant communities, including three upland communities on the natural levees and dredge spoil islands along the north edge of the island. In their study of the spread of *Spartina patens* on Cox Island, Frenkel and Boss (1988) described eight plant community types, grouping them on a map of the island into low marsh, middle marsh, high marsh, transition marsh, and forest. Brophy (2009) described the vegetation in three sample plots on Cox Island (near P2, P1, and P3 on Fig. 4, respectively): a high marsh community of *Juncus balticus, Argentina egedii, Distichlis spicata*, *Carex lyngbyei*, *Hordeum brachyantherum,* and *Deschampsia caespitosa* (~2.29 m NAVD88), a high-to-middle marsh community of *J. balticus*, *D. spicata, Atriplex patula,* and *Galium aparine* (~2.28 NAVD88), and a low marsh community of *Triglochin maritimum,* *D. spicata*, *Deschampsia caespitosa*, *Lilaeopsis occidentalis*, *Carex lyngbyei*, *Eleocharis parvula,* and *Schoenoplectus caespitosus* (~1.85 m NAVD88). Summer salinities at Brophy’s (2009) three sites were 19–20 ppt, whereas winter values were 2.5–5.0 ppt. In her study of modern foraminifera along transect M near location P4 on Fig. 4, Hawkes et al. (2010) described a middle marsh (1.6–2.0 m NAVD88) dominated by *J. balticus* and *C. lyngbyei*, and, on a natural levee (2.0–2.5 m NAVD88), a high marsh community of *D. caespitosa*, *A. egedii*, *J. balticus*, *D. spicata*, and *Jaumea carnosa*. In his study of modern diatoms along the same transect, Sawai et al. (2016) measured summer salinities in the high marsh of only 5-10 ppt.

**Sampling elevations**

Tides in the Siuslaw River estuary are semidiurnal and mesotidal. Hawkes et al. (2010) made tidal measurements over two days along the northeast bank of Cox Island and used tidal simulations run with a nonlinear hydrodynamic circulation model with 3-km nodes along the coast to estimate core and sample elevations. Their measurements are similar to (mean difference ~0.07 m) the elevations of Brophy (2009) obtained by leveling to benchmarks along Highway 126 (Fig. 2). We adopt tidal datums (referenced to the National Vertical Datum of 1988, NAVD88) calculated for northern Cox Island with vDatum (NOAA, 2018, accessed 31May18): Mean Higher High Water (MHHW), 2.30 ± 0.07 m; Mean High Water (MHW), 2.08 ± 0.06 m; Mean Tide Level (MTL), 1.12 ± 0.08 m; Mean Sea Level (MSL), 1.11 ± 0.06 m; Mean Low Water (MLW), 0.17 ± 0.12 m; and Mean Lower Low Water (MLLW), -0.23 ± 0.19 m. The means of these datums are within 0.02 m of the datums of Hawkes et al. (2010); tidal range is 2.53 m. Elevations for cores and samples collected in 2005–2008 on Cox Island were leveled with a total station to a temporary benchmark referenced to the tidal measurements of Hawkes et al. (2010).

**Part 4 - Radiocarbon-age errors adjusted with added variance**

Errors in the precision and accuracy of radiocarbon dating have been widely discussed since introduction of the method (Libby et al., 1949; Taylor, 1987; Trumbore, 2000; Bronk Ramsey, 2008; Taylor and Bar-Yosef, 2014). Radiocarbon ages listed in column 2 of Table 2 are those reported by the radiocarbon laboratory. By convention, the reported one standard deviation (1σ) errors for accelerator mass spectrometer ages from these laboratories are the larger of counting error or target reproducibility error. However, many laboratories have attempted to measure small additional errors introduced during the complete processing of routine samples in their laboratories. These additional errors are commonly referred to as “added variance.” Such errors do not include differences in ages on identical samples among different laboratories (e.g., Scott et al., 2010; Millard, 2014), or the commonly much greater uncertainties in sample stratigraphic context (e.g., Waterbuck, 1971; Taylor, 1987; Wright, 2017).

All but 6 of the 71 ages of Table 2 were measured by the National Ocean Sciences AMS Facility (NOSAMS) at Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. A recent (2015-2016) assessment of added variance on the modern fractions (used to calculate reported ages) measured on organic carbon samples submitted to the NOSAMS laboratory was 2.6o/oo (website accessed, 29 August 2019; e.g., Nelson et al., 2020; Atwater, 2020). Elder et al. (1998) estimated the added variance associated with sample processing at NOSAMS at 2.4o/oo for 73 sets of replicate samples of seawater, and 2.2o/oo for 24 sets of replicate samples of marine coral.

In this paper, because we use probability density function distributions derived from our radiocarbon age models to compare the times of earthquakes and their accompanying tsunamis from site to site (Fig. 12), it is important to accurately estimate analytical errors on our ages from the Siuslaw River estuary. For this reason, in our age models for Siuslaw River we increase the errors on the NOSAMS laboratory reported ages of Table 2 by adding 2.6o/oo of additional variance to the reported modern fraction values for these ages. These adjustments of added variance increase the 1σ errors on the reported ages by 3-80%, with a mean of 33%.

For many of the published ages from other sites that we used to develop the age models shown on Fig. 12, we lack fraction modern 14C values for ages as well as information about the possible need for added variance on age errors. For ages from 1987 to 1998 for these other sites with reported errors of <±80 14C yr BP, we increase the errors to ±80 14C yr BP (e.g., Nelson et al., 2020; Atwater, 2020), as suggested by Taylor et al. (1996). For the age intervals (purple bars on Fig. 12) from Willapa Bay, Atwater et al. (2004) and Hagstrum et al. (2004) used the added variance (error multipliers) of Stuiver and Pearson (1986; Atwater, 2020). Intervals for ages of turbidites (brown bars on Fig. 12) are those of Goldfinger et al. (2012; averaged corrected ages, Appendix 1, Land-marine data tab; see discussion of those ages in Atwater and Griggs, 2012). For other published and unpublished ages used in the age models of Fig. 12, we use the laboratory reported age and errors without modification.

**Part 5 - Radiocarbon code for OxCal age models using 14C ages from**

**Cox Island core S and outcrop 1, Siuslaw River estuary**

This section lists selected OxCal (version 4.3) age models used to evaluate radiocarbon dated samples collected above and below contacts A, B, C, Da, Db, Ea, Eb, Fa, Fb, G, H, and I in core S and at outcrop 1 (Table 2).

Plot(Siuslaw\_seq\_v9\_31Oct19)

{

// This is a non-outlier model using the Sequence command. Of the original 60 ages only 18 are used. Of the ages marked in bold on Table 2, we use only the youngest maximum age and oldest minimum age above and below contacts. None of the ages are grouped into phases. Where no minimum ages are available for a contact, or in the case of contact B no maximum ages, the Zero\_Boundary command is used to skew the age probability distributions towards the limiting ages for the contact.

Sequence("Siuslaw v9 31Oct19")

{

Boundary("base of sequence in cores S and K and section 1")

R\_Date("max I ARN08-9B", 2159, 36);

Date("contact I");

R\_Date("min I SLB-7-1", 2079, 38);

R\_Date("max H SLB-16-2", 1777, 28);

Date("contact H");

R\_Date("min? H SLB-16-1", 1672, 26);

R\_Date("max G ARN08-3A1", 1700, 30);

Date("contact G");

R\_Date("min G SLB-6-1", 1649, 48);

R\_Date("KBB-3", 1564, 44) {Outlier(0.05);};

Date("contact Fb");

R\_Date("max Fb KBB-2", 1546, 37);

R\_Date("max Fa KBB-5", 1577, 37);

Date("contact Fa");

R\_Date("min Fa SLB-10-1", 1423, 36);

R\_Date("max Eb SLB-4-1", 1051, 63);

Date("contact Eb");

Zero\_Boundary(“contact Eb”);

R\_Date("max Ea SLB-2-1", 990, 36);

Date("contact Ea");

Zero\_Boundary(“contact Ea”);

R\_Date("max Db SLB-1-3", 873, 35);

Date("contact Db");

R\_Date("SLB-19-1 min Db", 702, 27);

R\_Date("max Da ARN08-08E ", 821, 47);

Date("contact Da");

R\_Date("SLB-22-1 min Da", 467, 32);

R\_Date("max C SLB-13-3", 308, 27);

Date("contact C");

Zero\_Boundary(“contact C”);

Zero\_Boundary(“contact B”);

Date("contact B");

R\_Date("min B SLB-21-1", 207, 32);

R\_Date("max A SLB-12-2", 185, 33);

Date("contact A");

Zero\_Boundary(“contact A”);

Boundary("sequence end historic constraint", 1850);

};

};

Plot(Siuslaw\_outlier\_seq\_v8\_31Oct19)

{

// This is an Outlier model using the Sequence command. Of the 39 ages used in model v7, 4 are not used because they were identified as outliers in models v6 and v7 and(or) are inferred to be on detrital material much older or on roots much younger than the overlying contact. Two ages on the outermost rings of tree roots that probably include significant amounts of post-root carbon are not used. None of these ages, which are shown in bold on Table 2, are grouped into phases. Where no minimum ages are available for a contact, or in the case of contact B no maximum ages, the Zero\_Boundary command is used to skew the age probability distributions towards the available limiting ages for the contact.

Outlier\_Model("General", T(5), U(0,4),"t");

Sequence("Siuslaw v8 31Oct19")

{

Boundary("base of sequence in cores S and K and section 1")

R\_Date("ARN08-9B", 2159, 36) {Outlier(0.05);};

Date("contact I");

R\_Date("SLB-7-1", 2079, 38) {Outlier(0.05);};

R\_Date("SLB-7-2", 2033, 39) {Outlier(0.05);};

R\_Date("SLB-16-2", 1777, 28) {Outlier(0.05);};

Date("contact H");

R\_Date("SLB-16-3", 1707, 26) {Outlier(0.05);};

R\_Date("SLB-16-1", 1672, 26) {Outlier(0.05);};

R\_Date("SLB-6-2", 1743, 40) {Outlier(0.05);};

R\_Date("SLB-6-3", 1729, 66) {Outlier(0.05);};

R\_Date("ARN08-3A1", 1700, 30) {Outlier(0.05);};

Date("contact G");

R\_Date("SLB-8-1 min G", 1725, 37) {Outlier(0.05);};

R\_Date("SLB-6-1 min G", 1649, 48) {Outlier(0.05);};

R\_Date("KBB-3", 1564, 44) {Outlier(0.05);};

Date("contact Fb");

R\_Date("min Fb KBB-2", 1546, 37) {Outlier(0.05);};

R\_Date("min Fb KBB-4", 1520, 37) {Outlier(0.05);};

R\_Date("ARN08-7B ", 1591, 39) {Outlier(0.05);};

R\_Date("KBB-6", 1586, 43) {Outlier(0.05);};

R\_Date("max Fa KBB-5", 1577, 37) {Outlier(0.05);};

Date("contact Fa");

R\_Date("min Fa SLB-10-1", 1423, 36) {Outlier(0.05);};

R\_Date("SLB-3-1", 1097, 46) {Outlier(0.05);};

R\_Date("ARN08-4B min E", 1082, 38) {Outlier(0.05);};

R\_Date("SLB-4-1", 1051, 63) {Outlier(0.05);};

Date("contact Eb");

Zero\_Boundary(“contact Eb”);

R\_Date("SLB-2-2", 998, 35) {Outlier(0.05);};

R\_Date("SLB-2-1", 990, 36) {Outlier(0.05);};

Date("contact Ea");

Zero\_Boundary(“contact Ea”);

R\_Date("SLB-1-1", 911, 41) {Outlier(0.05);};

R\_Date("SLB-1-3", 873, 35) {Outlier(0.05);};

Date("contact Db");

R\_Date("SLB-19-1 min Db", 702, 27) {Outlier(0.05);};

R\_Date("ARN08-08E ", 821, 47) {Outlier(0.05);};

Date("contact Da");

R\_Date("SLB-22-1 min Da", 467, 32) {Outlier(0.05);};

R\_Date("ARN08-6B", 336, 35) {Outlier(0.05);};

R\_Date("SLB-13-2", 310, 35) {Outlier(0.05);};

R\_Date("SLB-13-3", 308, 27) {Outlier(0.05);};

Date("contact C");

Zero\_Boundary(“contact C”);

Zero\_Boundary(“contact B”);

Date("contact B");

R\_Date("min B SLB-21-1", 207, 32) {Outlier(0.05);};

R\_Date("max A ARN08-11B", 194, 34) {Outlier(0.05);};

R\_Date("max A SLB-12-2", 185, 33) {Outlier(0.05);};

Date("contact A");

Zero\_Boundary(“contact A”);

Boundary("sequence end historic constraint", 1850);

};

};

Plot(Siuslaw\_outlier\_seq\_v7\_31Oct19)

{

// This is an Outlier model using the Sequence command. Of the 60 ages used in model v6, 21 are not used because they were identified as outliers in model v6 and(or) are inferred to be on detrital material much older than the overlying contact. Two ages on the outermost rings of tree roots that probably include significant amounts of post-root carbon are not used. Where no minimum ages are available for a contact, or in the case of contact B no maximum ages, the Zero\_Boundary command is used to skew the age probability distributions towards the available limiting ages for the contact.

Outlier\_Model("General", T(5), U(0,4),"t");

Sequence("Siuslaw v7 31Oct19")

{

Boundary("base of sequence in cores S and K and section 1")

R\_Date("ARN08-9B", 2159, 36) {Outlier(0.05);};

Date("contact I");

Phase("min contact I")

{

R\_Date("SLB-7-1", 2079, 38) {Outlier(0.05);};

R\_Date("SLB-7-2", 2033, 39) {Outlier(0.05);};

};

Phase("max contact H")

{

R\_Date("KBB-1", 1973, 36) {Outlier(0.05);};

R\_Date("SLB-16-2", 1777, 28) {Outlier(0.05);};

};

Date("contact H");

Phase("min contact H")

{

R\_Date("SLB-16-3", 1707, 26) {Outlier(0.05);};

R\_Date("SLB-16-1", 1672, 26) {Outlier(0.05);};

};

Phase("max contact G")

{

R\_Date("SLB-6-2", 1743, 40) {Outlier(0.05);};

R\_Date("SLB-6-3", 1729, 66) {Outlier(0.05);};

R\_Date("ARN08-3A1", 1700, 30) {Outlier(0.05);};

};

Date("contact G");

Phase("min contact G")

{

R\_Date("SLB-8-1 min G", 1725, 37) {Outlier(0.05);};

R\_Date("SLB-6-1 min G", 1649, 48) {Outlier(0.05);};

};

R\_Date("KBB-3", 1564, 44) {Outlier(0.05);};

Date("contact Fb");

Phase("min contact Fb")

{

R\_Date("KBB-2", 1546, 37) {Outlier(0.05);};

R\_Date("KBB-4", 1520, 37) {Outlier(0.05);};

};

Phase("max contact Fa")

{

R\_Date("ARN08-7B ", 1591, 39) {Outlier(0.05);};

R\_Date("KBB-6", 1586, 43) {Outlier(0.05);};

R\_Date("KBB-5", 1577, 37) {Outlier(0.05);};

};

Date("contact Fa");

R\_Date("min Fa SLB-10-1", 1423, 36) {Outlier(0.05);};

Phase("max contact Eb")

{

R\_Date("SLB-3-1", 1097, 46) {Outlier(0.05);};

R\_Date("ARN08-4B min E", 1082, 38) {Outlier(0.05);};

R\_Date("SLB-4-1", 1051, 63) {Outlier(0.05);};

};

Date("contact Eb");

Zero\_Boundary(“contact Eb”);

Phase("max contact Ea")

{

R\_Date("SLB-2-2", 998, 35) {Outlier(0.05);};

R\_Date("SLB-2-1", 990, 36) {Outlier(0.05);};

};

Date("contact Ea");

Zero\_Boundary(“contact Ea”);

Phase("max contact Db")

{

R\_Date("ARN08-8C", 986, 43) {Outlier(0.05);};

R\_Date("SLB-1-1", 911, 41) {Outlier(0.05);};

R\_Date("SLB-1-3", 873, 35) {Outlier(0.05);};

};

Date("contact Db");

R\_Date("ARN08-08E ", 821, 47) {Outlier(0.05);};

R\_Date("SLB-19-1 min Db", 702, 27) {Outlier(0.05);};

Date("contact Da");

R\_Date("SLB-22-1 min Da", 467, 32) {Outlier(0.05);};

Phase("max contact C")

{

R\_Date("ARN08-6B", 336, 35) {Outlier(0.05);};

R\_Date("SLB-13-2", 310, 35) {Outlier(0.05);};

R\_Date("SLB-13-3", 308, 27) {Outlier(0.05);};

};

Date("contact C");

Zero\_Boundary(“contact C”);

Zero\_Boundary(“contact B”);

Date("contact B");

Phase("min contact B")

{

R\_Date("SLB-21-1", 207, 32) {Outlier(0.05);};

R\_Date("SLB-20-1", 101, 32) {Outlier(0.05);};

};

Phase("max contact A")

{

R\_Date("SLB-12-2", 185, 33) {Outlier(0.05);};

R\_Date("ARN08-11B", 194, 34) {Outlier(0.05);};

};

Date("contact A");

Zero\_Boundary(“contact A”);

Boundary("sequence end historic constraint", 1850);

};

};

Plot(Siuslaw\_outlier\_seq\_v6\_31Oct19)

{

// This is an Outlier model using the Sequence command. All (60) ages from cores S and K and outcrop 1 are placed above or below stratigraphic contacts depending on whether we assessed them as being detrital or in growth position. Most ages are further grouped into phrases, inferred to be older or younger than the nearest contact. Where no minimum ages are available for a contact, or in the case of contact B no maximum ages, the Zero\_Boundary command is used to skew the age probability distributions towards the available limiting ages for the contact (e.g., DuRoss et al., 2011).

Outlier\_Model("General", T(5), U(0,4),"t");

Sequence("Siuslaw v6 31Oct19")

{

Boundary("base of sequence in cores S and K and section 1")

Phase("max contact I")

{

R\_Date("SLB-18-1", 2318, 27) {Outlier(0.05);};

R\_Date("SLB-7-3", 2237, 44) {Outlier(0.05);};

R\_Date("ARN08-9B", 2159, 36) {Outlier(0.05);};

R\_Date("ARN08-9A", 2086, 36) {Outlier(0.05);};

};

Date("contact I");

Phase("min contact I")

{

R\_Date("SLB-7-1", 2079, 38) {Outlier(0.05);};

R\_Date("SLB-7-2", 2033, 39) {Outlier(0.05);};

};

Phase("max contact H")

{

R\_Date("SLB-9-1", 2095, 27) {Outlier(0.05);};

R\_Date("SLB-17-1", 2023, 27) {Outlier(0.05);};

R\_Date("KBB-1", 1973, 36) {Outlier(0.05);};

R\_Date("SLB-16-2", 1777, 28) {Outlier(0.05);};

};

Date("contact H");

Phase("min contact H")

{

R\_Date("SLB-16-3", 1707, 26) {Outlier(0.05);};

R\_Date("SLB-16-1", 1672, 26) {Outlier(0.05);};

};

Phase("max contact G")

{

R\_Date("ARN08-03B1 ", 1798, 26) {Outlier(0.05);};

R\_Date("SLB-6-2", 1743, 40) {Outlier(0.05);};

R\_Date("SLB-6-3", 1729, 66) {Outlier(0.05);};

R\_Date("ARN08-3A1", 1700, 30) {Outlier(0.05);};

};

Date("contact G");

Phase("min contact G")

{

R\_Date("SLB-8-1 min G", 1725, 37) {Outlier(0.05);};

R\_Date("SLB-6-1 min G", 1649, 48) {Outlier(0.05);};

};

Phase("max contact Fb")

{

R\_Date("SLB-14-2", 1668, 35) {Outlier(0.05);};

R\_Date("SLB-14-1", 1656, 35) {Outlier(0.05);};

R\_Date("ARN08-7A", 1632, 34) {Outlier(0.05);};

R\_Date("KBB-3", 1564, 44) {Outlier(0.05);};

};

Date("contact Fb");

Phase("min contact Fb")

{

R\_Date("KBB-2", 1546, 37) {Outlier(0.05);};

R\_Date("KBB-4", 1520, 37) {Outlier(0.05);};

};

Phase("max contact Fa")

{

R\_Date("ARN08-7B ", 1591, 39) {Outlier(0.05);};

R\_Date("KBB-6", 1586, 43) {Outlier(0.05);};

R\_Date("KBB-5", 1577, 37) {Outlier(0.05);};

R\_Date("SLB-11-1", 1334, 37) {Outlier(0.05);};

};

Date("contact Fa");

R\_Date("min Fa SLB-10-1", 1423, 36) {Outlier(0.05);};

Phase("max contact Eb")

{

R\_Date("ARN08-4A", 1275, 37) {Outlier(0.05);};

R\_Date("ARN08-4C ", 1121, 36) {Outlier(0.05);};

R\_Date("SLB-3-1", 1097, 46) {Outlier(0.05);};

R\_Date("ARN08-4B min E", 1082, 38) {Outlier(0.05);};

R\_Date("SLB-4-1", 1051, 63) {Outlier(0.05);};

};

Date("contact Eb");

Zero\_Boundary(“contact Eb”);

Phase("max contact Ea")

{

R\_Date("SLB-2-2", 998, 35) {Outlier(0.05);};

R\_Date("SLB-2-1", 990, 36) {Outlier(0.05);};

};

Date("contact Ea");

Zero\_Boundary(“contact Ea”);

Phase("max contact Db")

{

R\_Date("ARN08-8B", 1125, 33) {Outlier(0.05);};

R\_Date("ARN08-8A", 1058, 27) {Outlier(0.05);};

R\_Date("ARN08-8C", 986, 43) {Outlier(0.05);};

R\_Date("SLB-1-1", 911, 41) {Outlier(0.05);};

R\_Date("SLB-1-3", 873, 35) {Outlier(0.05);};

};

Date("contact Db");

R\_Date("SLB-19-1 min Db", 702, 27) {Outlier(0.05);};

Phase("max contact Da")

{

R\_Date("SLB-15-2", 1075, 26) {Outlier(0.05);};

R\_Date("ARN08-8D", 993, 27) {Outlier(0.05);};

R\_Date("SLB-15-1", 950, 26) {Outlier(0.05);};

R\_Date("ARN08-08E ", 821, 47) {Outlier(0.05);};

};

Date("contact Da");

R\_Date("SLB-22-1 min Da", 467, 32) {Outlier(0.05);};

Phase("max contact C")

{

R\_Date("SLB-13-1", 536, 39) {Outlier(0.05);};

R\_Date("ARN08-10A ", 480, 25) {Outlier(0.05);};

R\_Date("ARN08-6B", 336, 35) {Outlier(0.05);};

R\_Date("SLB-13-2", 310, 35) {Outlier(0.05);};

R\_Date("SLB-13-3", 308, 27) {Outlier(0.05);};

};

R\_Date("ARN08-6A ", 217, 41) {Outlier(0.05);};

Date("contact C");

Zero\_Boundary(“contact C”);

Zero\_Boundary(“contact B”);

Date("contact B");

Phase("min contact B")

{

R\_Date("SLB-21-1", 207, 32) {Outlier(0.05);};

R\_Date("SLB-20-1", 101, 32) {Outlier(0.05);};

};

Phase("max contact A")

{

R\_Date("SLB-12-1", 287, 33) {Outlier(0.05);};

R\_Date("ARN08-11A ", 283, 70) {Outlier(0.05);};

R\_Date("ARN08-11E ", 266, 37) {Outlier(0.05);};

R\_Date("SLB-12-2", 185, 33) {Outlier(0.05);};

R\_Date("ARN08-11B", 194, 34) {Outlier(0.05);};

};

Date("contact A");

Zero\_Boundary(“contact A”);

Boundary("sequence end historic constraint", 1850);

};

};

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