



HAL
open science

Tracking subducted ridges through intermediate-depth seismicity in the Vanuatu subduction zone

Christian Baillard, Wayne C. Crawford, Valérie Ballu, Bernard Pelletier,
Esline Garaebiti

► To cite this version:

Christian Baillard, Wayne C. Crawford, Valérie Ballu, Bernard Pelletier, Esline Garaebiti. Tracking subducted ridges through intermediate-depth seismicity in the Vanuatu subduction zone. *Geology*, 2018, 46 (9), pp.767-770. 10.1130/G45010.1 . hal-03009620

HAL Id: hal-03009620

<https://hal.science/hal-03009620>

Submitted on 29 Dec 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Tracking subducted ridges through intermediate-depth seismicity in the Vanuatu subduction zone

Tracking no: G45010R

Authors:

Christian Baillard (University of Washington School of Oceanography), Wayne Crawford (Institut de Physique du Globe de Paris), Valérie Ballu (Littoral ENvironnement et Sociétés), Bernard Pelletier (Institut pour la Recherche et le Développement), and Esline Garaebiti (Geohazards Section, Vanuatu Meteorology and Geohazards Department)

Abstract:

The distribution of intermediate-depth seismicity beneath the Vanuatu archipelago includes several seismic clusters/alignments and gaps, including a remarkable 200×150 km gap beneath central Vanuatu. We show that a zone of enhanced seismicity beneath this gap corresponds to the most likely trace of the subducted D'Entrecasteaux Ridge (DER) and that another region of aligned seismicity to the south may correspond to another significant, now disappeared ridge. We suggest that regions of aligned intermediate-depth seismicity beneath Vanuatu are traces of subducted oceanic features on the downgoing plate, probably caused by enhanced hydration beneath them prior to subduction. The seismic gap above the DER trace, previously interpreted as a tear in the slab, may instead be a region of reduced hydration due to thick/unfractured input crust, low bending of this crust before subduction and/or greater slab residence time at shallower subducted depths, the latter two being directly related to DER collision. We propose that an uneven distribution of intermediate-depth seismicity at subduction zones may provide a window to the history and effects of subducted oceanic features.

1 Tracking subducted ridges through intermediate-depth seismicity in the Vanuatu
2 subduction zone

3 **Christian Baillard¹, Wayne C. Crawford², Valérie Ballu³, Bernard Pelletier⁴ and Esline**
4 **Garaebiti⁵**

5 ¹*School of Oceanography, University of Washington, 1503 NE Boat St, 98105 Seattle, WA, US,*
6 *baillard@uw.edu*

7 ²*Institut de Physique du Globe de Paris, CNRS UMR 7154, Université Paris Diderot, 1 rue Jussieu,*
8 *75238 Paris cedex 05, France, crawford@ipgp.fr*

9 ³*Littoral ENvironnement et Sociétés (LIENSs), CNRS UMR 7266, Université de La Rochelle, 2 rue*
10 *Olympe de Gouges, 17000 La Rochelle, France, valerie.ballu@univ-lr.fr*

11 ⁴*Institut pour la Recherche et le Développement, Nouméa, New Caledonia, bernard.pelletier@ird.fr*

12 ⁵*Geohazards Section, Vanuatu Meteorology and Geohazards Department, PMB 9054, Lini Highway,*
13 *Number 2, Port Vila, Vanuatu, gesline@vanuatu.gov.vu*

14 **ABSTRACT**

15 The distribution of intermediate-depth seismicity beneath the Vanuatu archipelago includes
16 several seismic clusters/alignments and gaps, including a remarkable 200×150 km gap beneath
17 central Vanuatu. We show that a zone of enhanced seismicity beneath this gap corresponds to the
18 most likely trace of the subducted D'Entrecasteaux Ridge (DER) and that another region of aligned
19 seismicity to the south may correspond to another significant, now disappeared ridge. We suggest that
20 regions of aligned intermediate-depth seismicity beneath Vanuatu are traces of subducted oceanic
21 features on the downgoing plate, probably caused by enhanced hydration beneath them prior to
22 subduction. The seismic gap above the DER trace, previously interpreted as a tear in the slab, may
23 instead be a region of reduced hydration due to thick/unfractured input crust, low bending of this crust
24 before subduction and/or greater slab residence time at shallower subducted depths, the latter two
25 being directly related to DER collision. We propose that an uneven distribution of intermediate-depth
26 seismicity at subduction zones may provide a window to the history and effects of subducted oceanic
27 features.

28

29 **INTRODUCTION**

30 The ~500 km long Vanuatu archipelago overlies one of world's most seismically active
31 subduction zones, with an average of one magnitude 7+ earthquake recorded per year since 1972
32 (National Earthquake Information Center). The present-day convergence rate between the Vanuatu
33 islands and the subducting Australian plate varies from 120 mm/yr in the south to 160 mm/yr in the
34 north, but slows to 35 mm/yr in the center (Fig. 1) (Calmant et al., 2003; Bergeot et al., 2009). This
35 slowing, and the existence of uplift sequences affecting part of the forearc islands (up to 6 mm/yr over
36 the past 150 Ka) (Taylor et al., 2005), can be linked to the subduction of a large and irregular
37 bathymetric feature: the D'Entrecasteaux Ridge (DER). The DER, which extends back along the
38 Australian Plate to New Caledonia, appears to have entered into subduction 2-3 Ma at the Epi
39 reentrant, ~160 km to the south (Fig. 1); (Greene et al., 1994; Meffre and Crawford, 2001).

40 Intermediate depth seismicity (50-300 km depth) in the Vanuatu region is mostly
41 constrained by the global seismic network. Shallow seismicity (< 50 km depth) is constrained by a
42 temporary network that focused on the central forearc in 2008-9 (Baillard et al., 2015). Intermediate-
43 depth seismicity in the Vanuatu region falls on or near a Wadati-Benioff zone corresponding to the
44 subducting slab and is highly variable along-strike, with several clusters or alignments of intense
45 seismicity as well as several regions almost completely lacking seismicity (Fig. 2A). Most authors
46 associate variations in intermediate-depth seismicity with how much water is subducted and the depth
47 and temperatures at which dehydration embrittlement occurs (e.g., Hacker et al., 2003; Yamasaki and
48 Seno, 2003; Omori et al., 2004; Milsch and Scholz, 2005) and the maximum depth of this seismicity
49 is generally greater in colder subducting slabs than in warmer ones (Kirby et al., 1996; Omori et al.,
50 2004; Abers et al., 2013). Most of these observations and models are derived from differences
51 between subduction zones, but variations are also observed within some subduction zones (e.g.,
52 Eberhart-Phillips et al. (2013) for New Zealand and Shillington et al. (2015) for Alaska), where they
53 are generally explained as local differences in hydration prior to subduction associated with
54 differences in plate fabric orientation with respect to the trench axis.

55 In this study we show that a region of enhanced seismicity in Central Vanuatu (Area C in Fig. 2A)
56 corresponds to the most likely trace of the subducted DER. We suggest that the enhanced seismicity
57 results from dehydration processes of the oceanic crust and upper mantle beneath the DER and that
58 the aseismic region above it could be caused by lower hydration of surrounding slab. Other
59 alignments of intermediate-depth seismicity beneath Vanuatu could also correspond to subducted
60 bathymetric features, including one just north of the DER trace (Area N in Fig. 2A) and another 400
61 km to the south (Area S in Fig. 2A), in front of a possible subduction front reentrant (Figs. 1 and 2B).
62 The traces of these features could provide a means for determining the past geometry and effects of
63 subduction and collisions at the Vanuatu and other subduction zones.

64

65 **SEISMICITY VARIATIONS AROUND THE DER**

66 Regions of enhanced intermediate-depth seismicity are often associated with local
67 dehydration of minerals within the subducting slab as it descends (Eberhart-Phillips et al., 2013;
68 Shillington et al., 2015; Paulatto et al., 2017). The northern portion of the DER, composed of Eocene
69 magmas, can be described as a fossil transform fault or subduction zone that links up with the fossil
70 New-Caledonia subduction zone, which was mainly active during the Eocene. The southern portion of
71 the DER, including the Bougainville seamount (Fig. 4), can be considered as a Eocene volcanic arc
72 (Maillet et al., 1983; Collot et al., 1994; Schellart et al., 2006; Mortimer et al., 2014). The history and
73 nature of the DER indicate a highly fractured system, with deep faults allowing enhanced hydration to
74 oceanic mantle depths as has been observed at other subduction zones (e.g., Lefeldt & Grevemeyer,
75 2008; Lefeldt et al., 2009; Ivandic et al., 2010; Fujie et al., 2013; Shillington et al., 2015). The
76 relatively high thermal parameter of the Australian plate at intermediate depth (> 2400 : Text T1 and
77 Baillard et al., 2015) allows hydrous minerals to be carried deep in the mantle before dehydration.

78 We estimated the position of the subducted DER under the Vanuatu arc by fitting a curve on
79 the descending slab between the current point of collision and the point of collision 2-3 Ma projected
80 along the slab (Fig. S1 and Text T2). The position and the termination of this projected ridge
81 correspond to a region of enhanced intermediate-depth seismicity beneath the slab's biggest seismic
82 gap (Figs. 2A, 3 and S2). The trace of this enhanced seismicity extends from 100 to 200 km depth,
83 indicating upper oceanic mantle deserpentinization: oceanic crust eclogitization is generally limited to
84 < 150 km depth (e.g., Hacker et al., 2003b; Maruyama and Okamoto, 2007) and the apex of this
85 process is estimated at 75 km depth in Vanuatu (Baillard et al., 2015), whereas the apex of oceanic
86 mantle deserpentinization is estimated at 170–220 km for Vanuatu (Syracuse et al., 2010). Most
87 intermediate-depth Vanuatu earthquakes have N-S (Trench-parallel) strike directions, suggesting that
88 they are driven by slab pull forces (Christova et al., 2004), but some events along the DER trace have
89 E-W orientations (Fig. S3), consistent with the orientation of the DER horsts and grabens (Maillet et
90 al., 1983).

91 A 200 km wide “gap” in intermediate-depth seismicity from 50-200 km depth lies just above
92 and south of the aforementioned seismicity alignment (Area C in Fig. 2). The gap was previously

93 interpreted to be the signature of the subducted DER itself (Marthelot et al., 1985) or a tear in the
94 subducting slab (Prévot et al., 1991; Chatelain et al., 1992) but, based on more recent understanding
95 of the controls on intermediate-depth seismicity, we propose that it is a low hydration region. This
96 low hydration could be pre-existing or driven by the DER collision. The pre-existing North Loyalty
97 Basin is composed of a ~15 km thick, relatively unfractured oceanic crust (Pontoise et al., 1980;
98 Maillet et al., 1983), which may be relatively un-hydrated. The DER collision tends to flatten the
99 entry of the adjacent plate into subduction and slow the convergence rate, reducing the bending force
100 on that plate before subduction and increasing the time that the plate would spend at shallow depths.
101 This reduced bending at shallow depths could limit the penetration of faults and therefore the
102 hydration of the oceanic lower crust and upper mantle, while the long time at shallow subduction
103 depths would allow more time for eclogitization reactions in the crust to run their course before the
104 slab descends to intermediate-earthquake depths. If these last two “active” processes are indeed
105 important in reducing slab hydration, then the shift of the gap to the south with increasing depth
106 suggests that the slowed convergence currently observed around south Santo island is a long-term
107 feature which has migrated north with the DER collision zone.

108

109 **OTHER LINEATIONS OF INTERMEDIATE-DEPTH SEISMICITY**

110 Other lineations of intermediate-depth seismicity beneath Vanuatu may also be linked to
111 subducted oceanic features (Fig. 2A). One such feature starts just north of the DER lineation at
112 approximately 100 km depth and extends northward to ~200 km depth (Area N in Fig. 2A). It is, like
113 the DER trace, oblique to the convergence direction. This feature could be linked to a subducted
114 portion of the West Torres Plateau (Fig. 1), which is currently colliding offshore north Santo island,
115 causing the uplift of the Torres islands (Taylor et al., 1985). Similar to the DER trace, there is a
116 secondary cluster of events with E-W strike, suggesting the possible reactivation of pre-existing faults
117 (Fig. S3). Intermediate-depth seismicity also appears to be slightly reduced above this lineation.

118 Another strong lineation of intermediate-depth earthquakes is observed near Tanna and Erromango
119 islands (Area S in Fig. 2A). This feature does not correlate with any current seamounts or ridges on
120 the subducting plate, but a morphologic feature on the trench just southwest of Tanna (Figs. 1 and 2B)
121 could be a reentrant caused by an ancient collision front.

122 **DISCUSSION**

123 Lineations in intermediate-depth seismicity may reveal the subduction history at other subduction
124 zones where strongly hydrated oceanic features enter into subduction. For example, Nakajima and
125 Hasegawa (2006) observed a lineation of seismicity that could be linked to a subducted fracture zone.
126 Other examples include a lineation of intermediate-depth earthquakes beneath Ecuador, which
127 appears to correlate with the subducted prolongation of the Grijalva Fracture Zone (Fig. S4) and
128 similar correlations beneath Peru with the Nazca fracture zone and beneath Tonga-Kermadec with the
129 Louisville Ridge (Figs. S5-6).

130 Variations in intermediate-depth seismicity have been also observed to correlate with variations in
131 surface volcanic rheology (Eberhart-Phillips et al., 2013). Vanuatu intermediate-depth earthquake
132 lineations appear to correlate with along-arc variations in isotopic ratios (Fig. S7), high Ba/La and
133 Pb/Nd ratios are observed directly above subducted features, indicating possible enrichment by slab
134 derived fluids (Peate et al., 1997) released predominantly in the vicinity of the subducted features.
135 Finer-scale isotope measurements are needed to validate this hypothesis.

136 Where intermediate depth earthquakes do not correlate with present-day topographic features on the
137 subducting plate, they may help to identify subducted features with no remaining seafloor trace. Both
138 the enhanced seismicity and any seismic gaps around them could be studied to determine if there was
139 significant blocking or slowing of convergence when the feature subducted. Deducing the past history
140 of oceanic features could help both kinematic constructions of local plate history and our
141 understanding of the role of subducted oceanic features on arc magmatism.

142 **CONCLUSION**

143 Lineations and gaps in intermediate-depth seismicity beneath the Vanuatu arc appear to be associated
144 with deeply fractured subducted features. The clearest correlation is observed with the
145 D'Entrecasteaux ridge, whose most likely continuation beneath the Vanuatu arc corresponds to a
146 region of enhanced intermediate-depth seismicity within the subducted slab (Fig. 4). A large region
147 of reduced intermediate-depth seismicity above this zone may result from reduced oceanic/mantle
148 hydration there, either as an effect of pre-existing thick oceanic crust of the North Loyalty Basin or
149 because of processes related to reduced bending behind the DER collision zone: 1) reduced deep
150 hydration of pre-subducted slab through reduced bending and fault penetration and 2) increased
151 dehydration of subducted oceanic crust at shallow depths because of a longer residence there.

152 Other lineations that may be associated with subducted features include 1) an oblique zone just north
153 of the DER extension, which may correspond to the West Torres Plateau going back to a time when it
154 was closer to the location of the Torres forearc islands; 2) a dip-parallel zone beneath Tanna and
155 Erromango islands, which may be associated with a completely subducted hydrated ridge.

156 Such lineations may provide a picture of past shallow subduction zone features, which could be used
157 to model and/or explain past changes in seismicity and plate motions.

158

159 **ACKNOWLEDGMENTS**

160 We thank the Vanuatu Government and the Vanuatu Geohazards Observatory for their aid and
161 support. We also thank IPGP and the French Government for their support through the Ph.D.
162 Scholarship.

163 **REFERENCES CITED**

- 164 Abers, G.A., Nakajima, J., van Keken, P.E., Kita, S., and Hacker, B.R., 2013, Thermal–petrological
165 controls on the location of earthquakes within subducting plates: *Earth and Planetary Science*
166 *Letters*, v. 369–370, p. 178–187, doi: 10.1016/j.epsl.2013.03.022.
- 167 Baillard, C., Crawford, W.C., Ballu, V., Régnier, M., Pelletier, B., and Garaebiti, E., 2015, Seismicity
168 and shallow slab geometry in the central Vanuatu subduction zone: *Journal of Geophysical*
169 *Research: Solid Earth*, v. 120, no. 8, p. 5606–5623, doi: 10.1002/2014JB011853.
- 170 Bergeot, N., Bouin, M.N., Diament, M., Pelletier, B., Régnier, M., Calmant, S., and Ballu, V., 2009,
171 Horizontal and vertical interseismic velocity fields in the Vanuatu subduction zone from GPS
172 measurements: Evidence for a central Vanuatu locked zone: *Journal of Geophysical Research*, v.
173 114, no. B6, p. B06405, doi: 10.1029/2007JB005249.
- 174 Calmant, S., Pelletier, B., Lebellegard, P., Bevis, M., Taylor, F.W., and Phillips, D.A., 2003, New
175 insights on the tectonics along the New Hebrides subduction zone based on GPS results: *Journal*
176 *of Geophysical Research*, v. 108, no. B6, p. 2319, doi: 10.1029/2001JB000644.
- 177 Chatelain, J.-L., Molnar, P., Prévot, R., and Isacks, B., 1992, Detachment of part of the downgoing
178 slab and uplift of the New Hebrides (Vanuatu) Islands: *Geophysical Research Letters*, v. 19, no.
179 14, p. 1507–1510, doi: 10.1029/92GL01389.
- 180 Christova, C., Scholz, C.H., and Kao, H., 2004, Stress field in the Vanuatu (New Hebrides) Wadati -
181 Benioff zone inferred by inversion of earthquake focal mechanisms: *Journal of Geodynamics*, v.
182 37, no. 2, p. 125–137, doi: 10.1016/j.jog.2003.11.001.
- 183 Collot, J., Greene, H., Fisher, M., and Geist, E.L., 1994, Tectonic accretion and deformation of the
184 accretionary wedge in the North d’Entrecasteaux ridge-New Hebrides Island arc collision zone:
185 evidence from multichannel seismic reflection profiles and leg 134 results: *Proceedings of the*
186 *Ocean Drilling Program, Scientific Results*, v. 134.
- 187 Eberhart-Phillips, D., Reyners, M., Faccenda, M., and Naliboff, J., 2013, Along-strike variation in

188 subducting plate seismicity and mantle wedge attenuation related to fluid release beneath the
189 North Island, New Zealand: *Physics of the Earth and Planetary Interiors*, v. 225, p. 12–27, doi:
190 10.1016/j.pepi.2013.10.002.

191 Fujie, G., Kodaira, S., Yamashita, M., Sato, T., Takahashi, T., and Takahashi, N., 2013, Systematic
192 changes in the incoming plate structure at the Kuril trench: *Geophysical Research Letters*, v. 40,
193 no. 1, p. 88–93, doi: 10.1029/2012GL054340.

194 Greene, H., Collot, J., Fisher, M.A., and Crawford, A., 1994, NEOGENE TECTONIC EVOLUTION
195 OF THE NEW HEBRIDES ISLAND ARC : A REVIEW INCORPORATING ODP DRILLING
196 RESULTS: *Proceedings of the Ocean Drilling Program, Scientific Results*, v. 134.

197 Hacker, B.R., Peacock, S.M., Abers, G.A., and Holloway, S.D., 2003, Subduction factory 2. Are
198 intermediate-depth earthquakes in subducting slabs linked to metamorphic dehydration
199 reactions? *Journal of Geophysical Research: Solid Earth*, v. 108, no. B1, p. 2030, doi:
200 10.1029/2001JB001129.

201 Ivandic, M., Grevemeyer, I., Bialas, J., and Petersen, C.J., 2010, Serpentinization in the trench-outer
202 rise region offshore of Nicaragua: constraints from seismic refraction and wide-angle data:
203 *Geophysical Journal International*, v. 180, no. 3, p. 1253–1264, doi: 10.1111/j.1365-
204 246X.2009.04474.x.

205 Kirby, S., Engdahl, R., and Denlinger, R., 1996, Intermediate-depth intraslab earthquakes and arc
206 volcanism as physical expressions of crustal and uppermost mantle metamorphism in subducting
207 slabs: *Geophysical Monograph Series*, p. 195–214, doi: 10.1029/GM096p0195.

208 Lefeldt, M., and Grevemeyer, I., 2008, Centroid depth and mechanism of trench-outer rise
209 earthquakes: *Geophysical Journal International*, v. 172, no. 1, p. 240–251, doi: 10.1111/j.1365-
210 246X.2007.03616.x.

211 Lefeldt, M., Grevemeyer, I., and Göbner, J., 2009, Intraplate seismicity and related mantle hydration at
212 the Nicaraguan trench outer rise: *Geophysical Journal*,.

213 Maillet, P., Monzier, M., Selo, M., and Storzer, D., 1983, The D'Entrecasteaux Zone (Southwest
214 Pacific). A petrological and geochronological reappraisal: *Marine Geology*, v. 53, no. 3, p. 179–
215 197, doi: 10.1016/0025-3227(83)90073-7.

216 Marthelot, J., Chatelain, J., Isacks, B., Cardwell, R., and Coudert, E., 1985, Seismicity and attenuation
217 in the central Vanuatu (New Hebrides) islands : a new interpretation of the effect of subduction
218 of the D'Entrecasteaux fracture zone: *Journal of Geophysical Research*, v. 90, p. 8641–8650.

219 Maruyama, S., and Okamoto, K., 2007, Water transportation from the subducting slab into the mantle
220 transition zone: *Gondwana Research*, v. 11, no. 1–2, p. 148–165, doi: 10.1016/j.gr.2006.06.001.

221 Meffre, S., and Crawford, A.J., 2001, Collision tectonics in the New Hebrides arc (Vanuatu): *The*
222 *Island Arc*, v. 10, no. 1, p. 33–50, doi: 10.1046/j.1440-1738.2001.00292.x.

223 Milsch, H.H., and Scholz, C.H., 2005, Dehydration-induced weakening and fault slip in gypsum:
224 Implications for the faulting process at intermediate depth in subduction zones: *Journal of*
225 *Geophysical Research: Solid Earth*, v. 110, no. B4, p. 1–16, doi: 10.1029/2004JB003324.

226 Mortimer, N., Gans, P.B., Palin, J.M., Herzer, R.H., Pelletier, B., and Monzier, M., 2014, Eocene and
227 oligocene basins and ridges of the coral sea-new caledonia region: Tectonic link between
228 melanesia, fiji, and zealandia: *Tectonics*, v. 33, no. 7, p. 1386–1407, doi:
229 10.1002/2014TC003598.

230 Nakajima, J., and Hasegawa, A., 2006, Anomalous low-velocity zone and linear alignment of
231 seismicity along it in the subducted Pacific slab beneath Kanto, Japan: Reactivation of
232 subducted fracture zone? *Geophysical Research Letters*, v. 33, no. 16, p. L16309, doi:
233 10.1029/2006GL026773.

234 Omori, S., Komabayashi, T., and Maruyama, S., 2004, Dehydration and earthquakes in the subducting
235 slab: empirical link in intermediate and deep seismic zones: *Physics of the Earth and Planetary*
236 *Interiors*, v. 146, no. 1–2, p. 297–311, doi: 10.1016/j.pepi.2003.08.014.

237 Paulatto, M., Laigle, M., Galve, A., Charvis, P., Sapin, M., Bayrakci, G., Evain, M., and Kopp, H.,

238 2017, Dehydration of subducting slow-spread oceanic lithosphere in the Lesser Antilles: Nature
239 Communications, v. 8, no. May, p. 15980, doi: 10.1038/ncomms15980.

240 Peate, D.W., Pearce, J. a., Hawkesworth, C.J., Colley, H., Edwards, C.M.H., and Hirose, K., 1997,
241 Geochemical Variations in Vanuatu Arc Lavas: the Role of Subducted Material and a Variable
242 Mantle Wedge Composition: *Journal of Petrology*, v. 38, no. 10, p. 1331–1358, doi:
243 10.1093/etroj/38.10.1331.

244 Pontoise, B., Latham, G., Daniel, J., Dupont, J., and Ibrahim, B., 1980, Seismic refraction studies in
245 the New Hebrides and Tonga area: UN ESCAP, CCOP/SOPAC Tech. Bull, p. 47–58.

246 Prévot, R., Roecker, S.W., Isacks, B.L., and Chatelain, J.L., 1991, Mapping of low P wave velocity
247 structures in the subducting plate of the central New Hebrides, southwest Pacific: *Journal of*
248 *Geophysical Research: Solid Earth*, v. 96, no. B12, p. 19825–19842, doi: 10.1029/91JB01837.

249 Schellart, W.P., Lister, G.S., and Toy, V.G., 2006, A Late Cretaceous and Cenozoic reconstruction of
250 the Southwest Pacific region: Tectonics controlled by subduction and slab rollback processes:
251 *Earth-Science Reviews*, v. 76, no. 3–4, p. 191–233, doi: 10.1016/j.earscirev.2006.01.002.

252 Shillington, D.J., Bécel, A., Nedimović, M.R., Kuehn, H., Webb, S.C., Abers, G. a., Keranen, K.M.,
253 Li, J., Delescluse, M., and Mattei-Salicrup, G. a., 2015, Link between plate fabric, hydration and
254 subduction zone seismicity in Alaska: *Nature Geoscience*, v. 8, no. 12, p. 961–964, doi:
255 10.1038/ngeo2586.

256 Syracuse, E.M., van Keken, P.E., and Abers, G. a., 2010, The global range of subduction zone
257 thermal models: *Physics of the Earth and Planetary Interiors*, v. 183, no. 1–2, p. 73–90, doi:
258 10.1016/j.pepi.2010.02.004.

259 Taylor, F.W., Jouannic, C., and Bloom, A.L., 1985, Quaternary Uplift of the Torres Islands, Northern
260 New Hebrides Frontal Arc: Comparison with Santo and Malekula Islands, Central New
261 Hebrides Frontal Arc: *The Journal of Geology*, v. 93, no. 4, p. 419–438, doi: 10.1086/628964.

262 Taylor, F.W., Mann, P., Bevis, M.G., Edwards, R.L., Cheng, H., Cutler, K.B., Gray, S.C., Burr, G.S.,

263 Beck, J.W., Phillips, D. a., Cabioch, G., and Recy, J., 2005, Rapid forearc uplift and subsidence
264 caused by impinging bathymetric features: Examples from the New Hebrides and Solomon arcs:
265 Tectonics, v. 24, no. 6, p. n/a-n/a, doi: 10.1029/2004TC001650.

266 Yamasaki, T., and Seno, T., 2003, Double seismic zone and dehydration embrittlement of the
267 subducting slab: Journal of Geophysical Research: Solid Earth, v. 108, no. B4, p. 2212, doi:
268 10.1029/2002JB001918.

269

270

271 **FIGURE CAPTIONS**

272 Figure 1. The Vanuatu archipelago. Main islands with active volcanoes are filled in red. White arrows
273 indicate the interseismic convergence rates along the subduction front (Calmant et al., 2003; Bergeot
274 et al., 2009). Contour with triangles shows subduction front and solid black contour is the 3500 m
275 depth contour on the island arc side of the subduction front. White rounded boxes surround the Epi
276 and Tanna reentrants. The tilted black box shows the bounds used for the along-arc view in Fig 2. AP:
277 Australian Plate; NFB: North Fiji Basin; DER: D'Entrecasteaux Ridge; NLoB: North Loyalty Basin.

278 Figure 2. Along-arc view of Vanuatu seismicity and reentrants. Positions of active volcanoes are
279 indicated by red triangles, other major islands by black bars. A) Earthquakes since 1972 (circles) as a
280 function of depth. "Seismic gap" is outlined by polygons with dashed borders and seismicity
281 clusters/alignments are outlined by rounded boxes. B) Distance between the subduction front and the
282 3500 m depth contour shown in Fig.1. The Tanna and Epi reentrants are labeled.

283 Figure 3. Seismicity from global and 2008-9 local networks and the projected subducted DER. Red
284 line is the constant curvature model of the DER shown in Fig. S1. Dashed lines are the limits for
285 different long-term convergence rates and DER shapes.

286 Figure 4. Conceptual figure showing how the distribution of intermediate-depth earthquakes (red
287 stars) relates to subducted topographic features. The dense fracture systems associated with these
288 features favor hydration of oceanic crust and upper mantle prior to subduction. Hydrous minerals are
289 then progressively dehydrated with increasing depth, triggering intermediate-depth earthquakes.
290 Dehydration progresses from the oceanic crust at lower depths (eclogitization) to the oceanic upper
291 mantle at greater depths (deserpentinization). The region of white rounded shapes indicates the
292 seismogenic zone. SB: Sabine Bank; BS: Bougainville Seamount; Gbr: Gabbro; Bsh: Blue Schist;
293 Prd: Peridotite; Srp: Serpentine

Figure 40° 160° 180°
0°

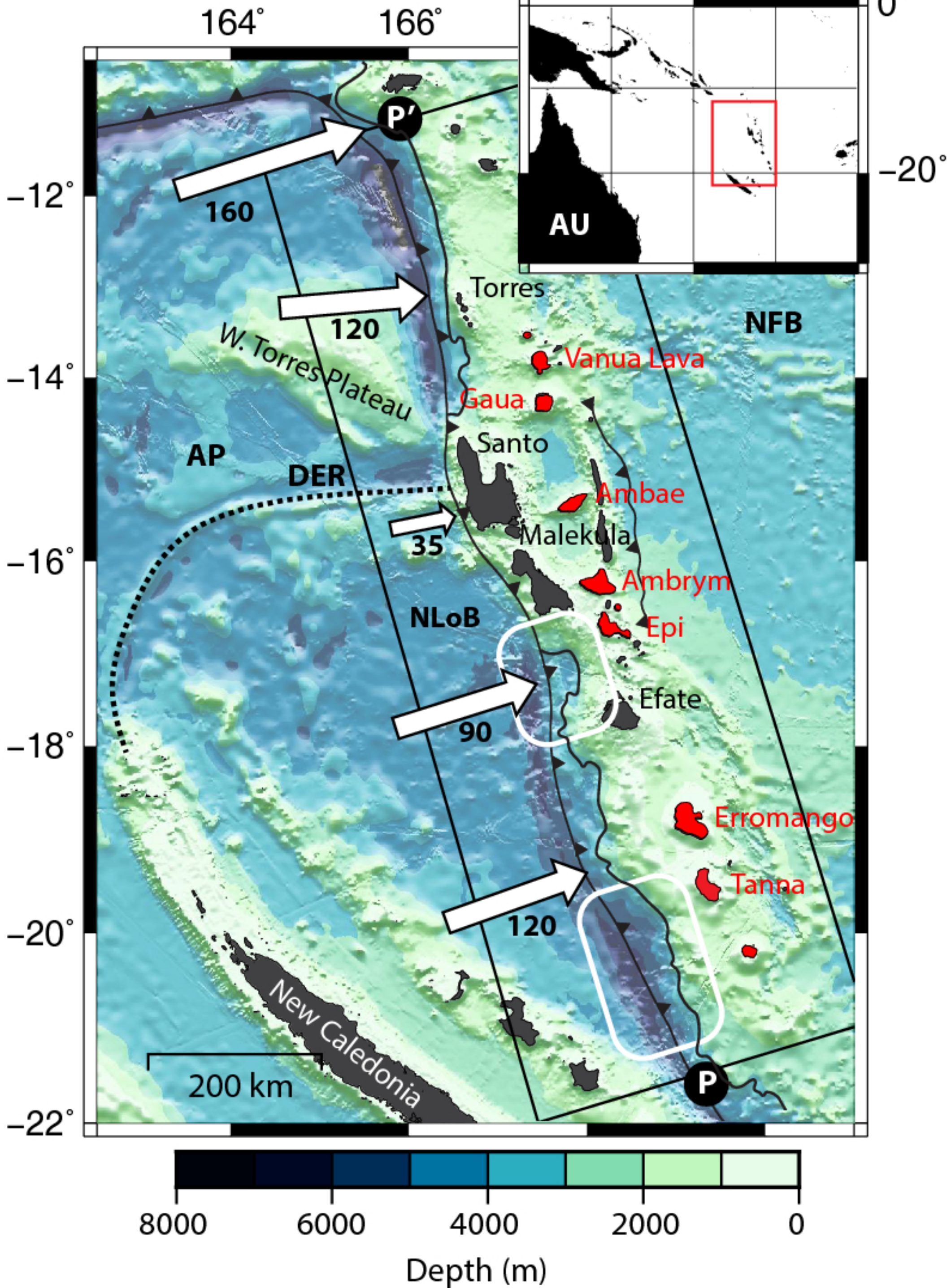


Figure 2

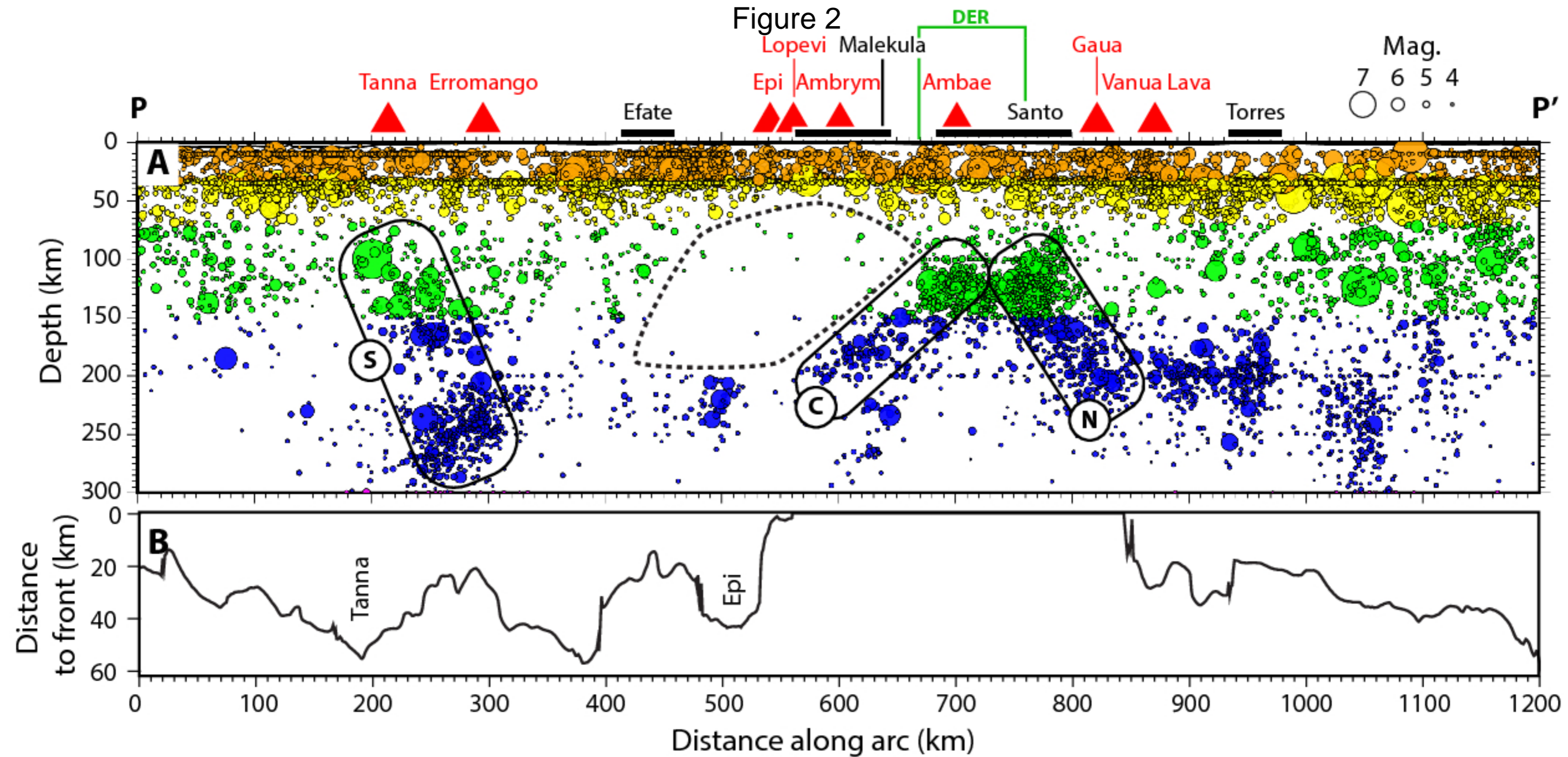


Figure 3

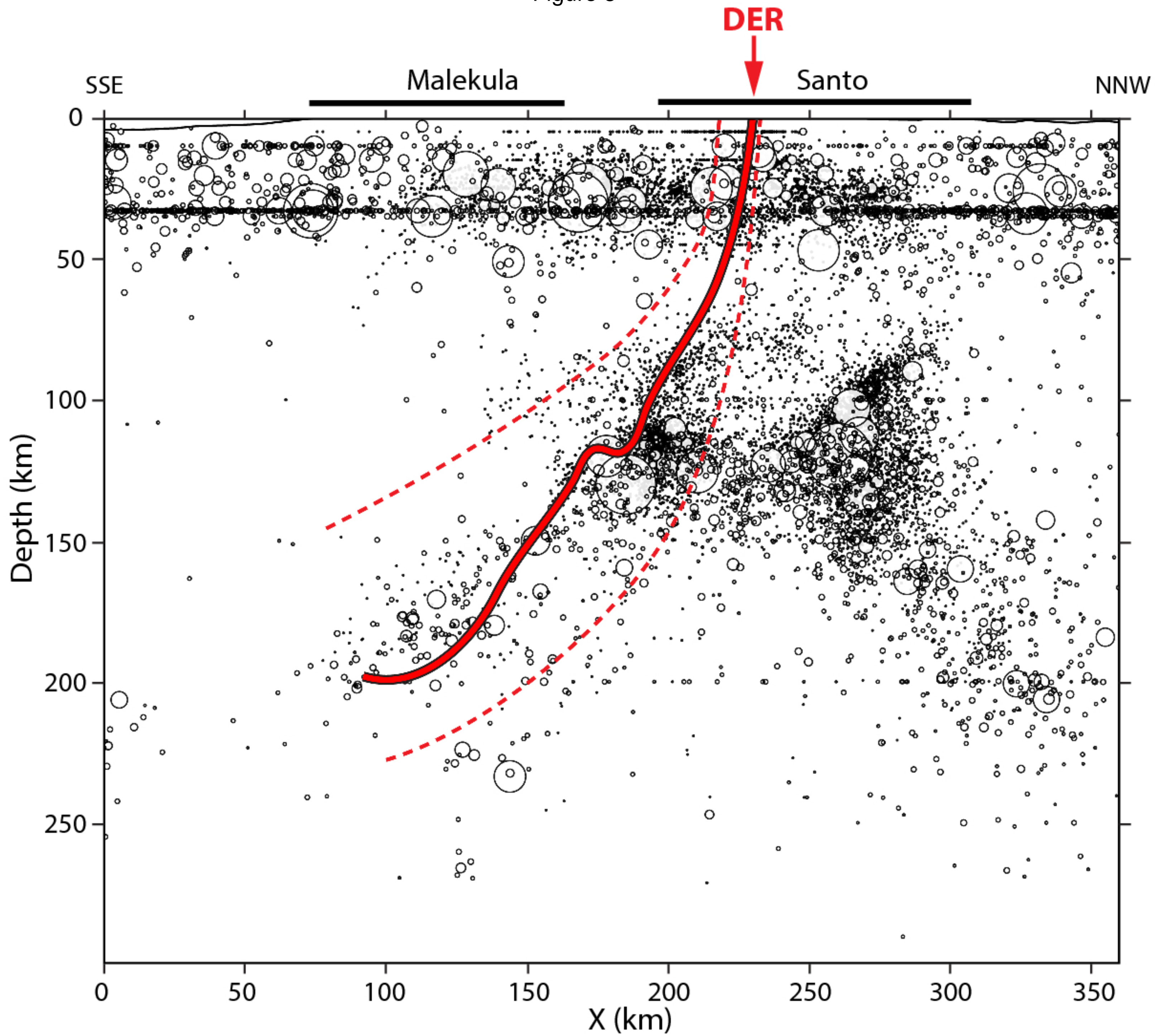


Figure 4

