UNIVERSITY OF LEEDS

1 # Controls on the origin and evolution of deep-ocean trench-axial

2 # channels

3 **Adam D. McArthur, Daniel E. Tek**

4 *School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, United Kingdom*
5 **ABSTRACT**

6 The type and volume of sediment entering subduction zones affects the style of plate

7 boundary deformation and thus sedimentary and tectonic cycles. Because submarine channels

8 significantly increase the transport efficiency of turbidity currents, their presence or absence in

9 subduction trenches is a primary control on trench fill. To date, comprehensive architectural

10 characterization of trench-axial channels has not been possible, undermining efforts to identify

11 the factors controlling their initiation and evolution. Here, we describe the evolution of the

12 Hikurangi Channel, which traverses the Hikurangi Trench, offshore New Zealand. Analysis of

13 2D and 3D seismic data reveals that the channel was present only during the last ~3.5 Myr of the

14 ~27 Myr of the trench's existence; its inception and propagation resulted from increased

15 sediment supply to the trench following amplified hinterland exhumation. To test if the controls

16 on the evolution of the Hikurangi Channel are universal, multivariate statistical analysis of the

17 geomorphology of subduction trenches globally is used to investigate the formative conditions of

18 axial channels in modern trenches. Terrigenous sediment supply and thickness of sediment cover

19 in a trench are the dominant controls; subsidiary factors such as trench length and rugosity also

20 contribute to the conditions necessary for trench-axial channel development. Axial channels

21 regulate sediment distribution in trenches and this varies temporally and spatially as a channel

22 propagates along a trench. The presence of a trench-axial channel affects plate boundary

23 mechanics and has implications for the style of subduction margin deformation.

24   **INTRODUCTION**

25   Ocean trenches represent one of the last frontiers for exploration on Earth. Modern

26   trenches are typically associated with forearc subduction margins and areally represent 0.5 % of

27   the ocean floors (Harris et al., 2014). Some trenches host axial channels; others do not.

28   Submarine channels are important drainage networks, transporting large volumes of terrigenous

29   sediment, including organic carbon (e.g. Omura et al., 2017) and pollutants (e.g. Kane et al.,

30   2020) into and within the deep-sea. Trench-axial channels regulate the volume, type and

31   distribution of sediment in a trench. Sediment type, i.e. fine (hemi-) pelagic sediments *vs.* coarser

32   terrigenous siliciclastic material, volume and distribution influence the mechanics of a

33   subduction interface (Rabinowitz et al., 2018), the growth of accretionary prisms (Lewis and

34   Hayes, 1984) and hence the nature of deformation at plate margins (Barnes et al., 2020). Despite

35   their societal and scientific importance, the factors that control the presence or absence of axial

36   channels and their stratigraphic evolution are poorly understood.

37   Although seafloor studies show the presence of trench-axial channels (e.g. Moore et al.,

38   1982a; Thornburg et al., 1990; Lewis 1994), a lack of subsurface data in trenches has hitherto

39   inhibited characterisation of their stratigraphic architecture and evaluation of factors controlling

40   their existence and evolution. To attempt these tasks, a subsurface investigation of the Hikurangi

41   Trench and its axial channel is performed (Fig. 1), to discern the controls on channel formation

42   and stratigraphic evolution. This subsurface investigation uses the first 3D seismic survey to

43   image a forearc trench-axial channel and an expansive 2D survey covering much of the trench.

44   To test the findings from the Hikurangi Margin, insights from this case study are used to inform

45   a comparative analysis of active subduction trenches globally. A better understanding of the

46   controls on the origin and evolution of trench-axial channels is essential to better understand the

47   erosion, transport and deposition of sediments, from land to the deep-ocean and their recycling at

48   plate boundaries, with implications for the tectonostratigraphic evolution of subduction zones.

49   **DATA AND METHODS**

50   Our dataset comprises >5000 line-kilometers of 2D and 2600 km^2 of 3D seismic data (see

51   supplementary material S1-4). Data are displayed SEG positive; a downward decrease in

52   acoustic impedance is shown as a trough (white reflection). Key surfaces (Fig. 2) were mapped

53   in accordance with the chronostratigraphic framework of Ghisetti et al. (2016). Dimensional and

54   morphometric measurements from global trenches were obtained using data within Geomap

55   App© and published papers (see S5 and S6). Principle component analysis was conducted on the

56   trench dataset to investigate the factors associated with the presence of axial channels.

57   **THE HIKURANGI CHANNEL**

58   **Geological Setting**

59   The SW-NE trending Hikurangi Trench developed over the last 27 Ma by subduction of

60   the Pacific Plate beneath the Australian Plate (Ballance, 1976; Jiao et al., 2014). Convergence

61   rates have increased through the subduction event (Nicol et al., 2007). The southern end of the

62   margin demonstrates a seismically locked plate interface; slow-slip events are occurring in the

63   north (Fig. 1; Wallace and Beavan, 2010). The Hikurangi Trench sits under 2600 to 3600 m of

64   water (Fig. 1). Trench fill, interpreted to be dominantly <3.5 Ma (Ghisetti et al. 2016; Kroeger et

65   al., 2019), thins from ~6 km of sediment in the SW, to <1 km in the NE, where the channel

66   deviates out of the trench (Lewis, 1994). The fill consists of relatively monotonous reflectors

67   interpreted as (hemi-) pelagic, turbidite, mass-transport and contourite deposits (McArthur et al.,

68   2019). Trench traversing flows are sourced by the flushing of slope canyons of the NE South

69   Island and SE North Island (Fig. 1; Mountjoy et al., 2018).

70   Key events in the margin's history include: (a) North Island exhumation ~27–20 Ma (Jiao

71   et al., 2014); (b) reconfiguration and uplift of the South Island from ~12-5 Ma (Tippett and

72   Kamp, 1993), resulting in increased exhumation rates of both islands at ~6–4 Ma (Jiao et al.,

73   2017); (c) the onset of Taupo volcanism ~2 Ma (Acocella et al., 2003); (d) a Plio-Pleistocene

74   increase in the amplitude of glacio-eustatic sea-level changes, which increased sediment flux

75   (Haywick et al., 1992).

76   **Channel Inception and Stratigraphic Evolution**

77   *Pre-channel strata*

78   A distinct horizon (R5b), dated as >3.5 Ma by Ghisetti et al. (2016), occurs at 6.5 –0.5

79   km depth in the south (Fig. 2A) and can be traced along the trench, occurring at 5 – 0.35 km

80   depth in the north (Fig. 2B). This surface and underlying reflectors dip at up to 14° to the NW.

81   Although often deformed, reflectors below are uniform, moderate in amplitude and frequency.

82   Reflectors above the surface onalp onto it, are flat to gently dipping and exhibit variable

83   amplitude and frequency. This deepest trench fill is imaged as a monotonous package of

84   reflectors, potentially representing turbidity current deposits in the south (Fig. 2A), which thins

85   to the north where drilling identified coeval pelagic sediments (Fig. 2B; Barnes et al., 2020).

86   *Isolated channel forms*

87   The deepest preserved axial channel fills are isolated channel forms that stack vertically

88   and to the SE and lack recognizable levees (Fig. 2C and F). In the south of the trench they are

89   present through several hundred meters of strata (Fig. 2A); they terminate within the trench and

90   are absent in the north (Fig. 2B). The formative conduits of these channel fills were relatively

91   small (<5 km wide), linear and dominantly erosional; they distributed sediment in the trench.

92   *Leveed channel forms*

93   A distinct change in reflector style occurs at ~800 m depth subsurface, above which

94   channel fills are aggradational, generally wider (2.5-10 km wide) and are bounded by compound

95   levees hundreds of meters thick (Fig. 2D and E). This change in reflector style is interpreted to

96   have occurred at ~1 Ma (Ghisetti et al., 2016). As opposed to the early channel forms that show

97   significant lateral offset (Fig. 2F), channels within the upper interval typically follow the course

98   of their predecessor, exhibiting little lateral offset but greater sinuosity (Fig. 2G). Within this

99   interval the channel system was never completely abandoned, with the exception of downsteam

100   reach cut-off following a major avulsion (Fig. 2B), due to channel deflection around a seamount.

101   *Controls on Hikurangi Channel inception and evolution*

102   Propogation of the Hikurangi Channel along the trench began ~3.5 Ma. Channel

103   inception, marked by the transition from background sediments to isolated channel forms that

104   terminate in the trench, ties to an acceleration of the exhumation of New Zealand between 6 and

105   4 Ma (Jiao et al., 2017), albeit with a temporal lag for increased sediment flux to reach the

106   trench. Amplified delivery of sediment to the trench resulted in increasing lateral flow

107   confinement, promoting channelization (Tek et al., 2020). At its initiation the channel was

108   unable to persist significant distances along the trench; only when suffcient sediment cover

109   supressed trench rugostiy was the channel able to propogate 630 km along the trench.

110   **COMPARISON WITH GLOBAL TRENCHES**

111   To test whether the controls on the inception and evolution of the Hikurangi Channel are

112   important globally, thirty-six trenches, located at convergent oceanic margins, are analysed to

113   investigate the controls on the presence of axial channels. Fourteen of these trenches contain

114   axial channels (see S5). Principle components analysis of twenty-three geomorphological factors

115   reveals trench length, thickness of sedimentary cover and sediment supply as the primary factors

116   that control development of trench-axial channels (Fig. 3). Sediment supply is the volume of

117   sediment transferred to a trench by axial or transverse flows (Underwood and Karig, 1980);

118   sedimentary cover is the total thickness of sediment accumulated in a trench, including accreted

119   sediments (Moore and Karig, 1976), meaning it is affected by the subduction rate and other types

120   of subaqueous processes; the two factors are therefore distinct.

121   **Trenches with axial channels**

122   Channel-bearing trenches are well supplied by terrigenous sediment, fed via slope

123   bypassing canyons. Three end-members can be identified:

124   1) Trenches containing channels that traverse their host trench for kilometers to

125   thousands of kilometers, before terminating in a trench-hosted fan (e.g. southern Chile Trench,

126   Thornburg et al., 1990).

127   2) Trenches containing stretches of channels tens to hundreds of kilometers long, which

128   escape their confines to terminate on the subducting plate. Channels may escape if the trench is

129   blocked by seamounts or landslides (e.g. the Hikurangi Channel, Lewis et al., 1998).

130   3) Trenches in which slope channels continue uninterrupted onto the subducting plate

131   (e.g. Cascadia, Komar, 1973). Here, sedimentation rates outpace subsidence and the trench is

132   infilled. While these trenches do not presently demonstrate axial channels, their fill may contain

133   deposits of ancient axial channels, formed when the trench had negative relief.

134   Channel-bearing trenches contain sufficient sedimentary fill, derived axially or from

135   transverse systems, to suppress the trench rugosity, therefore permitting uninterrupted axial flow

136   and channelization.

137   **Trenches without axial channels**

138   Trenches may not contain axial channels because:

139   1) They lack adequate terriginous sediment supply to form one (e.g. most trenches of the

140   SW Pacific, Clift et al., 1998).

141   2) Trench rugosity is prominent and cannot be suppressed by sediment influx. In such

142   cases, ponding against topographic obstacles inhibits channelization, even when sediment supply

143   is high (e.g. the Izu-Ogasawara Trench, Soh et al., 1988).

144   3) Although a subduction margin may be well supplied with sediment, trenches may have

145   a limited sediment supply due to trapping of sediment in trench-slope basins (e.g. Japan Trench,

146   von Huene et al., 1982).

147   **CONTROLS ON THE PRESENCE OF TRENCH-AXIAL CHANNELS**

148   Most trenches don't contain axial channels (Fig. 3). A sustained supply of terrigenous

149   sediment is essential to instigate and sustain a trench-axial channel system (Underwood and

150   Karig, 1980); however, this alone does not necessitate the presence of an axial channel, e.g. the

151   Calabrian Trench (Polonia et al., 2011). A sediment supply threshold exists: enough sediment

152   must be supplied to the trench to heal trench rugosity, preventing ponding of turbidites and

153   facilitating the flow run-out required for channelization (Underwood and Karig, 1980). This

154   threshold is not static, but inherently linked to convergence rates and trench rugosity at each

155   margin; trenches with high subduction rates and prominent intra-trench topography require

156   greater sediment supply to generate an axial channel (Underwood and Bachman, 1982). The

157   presence of trench rugosity, such as that formed by transform faults or by seamounts within the

158   trench don't rule out the existence of an axial channel, merely that the channel may not persist

159   far along the trench (e.g. Moore et al., 1982b).

160   Trench-axial channels form when sediment supply is sufficient to suppress trench

161   rugosity, but not to completely fill the trench. However, localized trench occlusion due to

162   landslides or subducting plate topography may divert channels away from the trench (e.g. Lewis

163   et al., 1998). Trench length is a controlling factor for the presence of an axial channel simply

164   because the longer a trench, the more likely the conditions to facilitate channelization will be

165   met.

166   Insights from the Hikurangi Margin and comparative analysis suggest a common model

167   for the formation and evolution of trench-axial channels (Fig. 4). At the onset of subduction,

168   when a trench is topographically complex, it is unlikely that terrestrial drainage networks can

169   supply enough sediment to allow the formation of an axial channel. Sediment starved trenches

170   with high rugosity cannot support axial channels; sediment entering the trench ponds in local

171   accommodation (Fig. 4A), e.g. the Tonga Trench (Clift et al., 1998). Ongoing convergence,

172   uplift and exhumation of the upper plate result in increasing terrestrial drainage and sediment

173   supply to the trench, promoting trench fill.

174   Aggrading trench fill suppresses trench rugosity and a short axial channel may form,

175   building a sedimentary wedge along the trench that permits channel propagation along the trench

176   before terminating (Fig. 4B), e.g. the Bougainville Trench (Tiffin et al., 1987). As a trench

177   matures, lateral confinement increases and sediment supply continues to rise, its axial channel

178   may propagate for tens to thousands of kilometers along the trench, e.g. the Chile Trench

179   (Thornburg et al., 1990). Finally, a trench may become filled with enough sediment to lose its

180   topographic expression, allowing channels to avulse and for trench-perpendicular channels to

181   become established (Fig. 4C), e.g. Cascadia (Komar, 1973).

182   Although factors such as trench-axial gradient and climatic change have been inferred to

183   exert a primary control on the presence of axial channels (Ness and Kulm, 1973; Underwood and

184   Bachman, 1982), this study shows that they play a minor role. For example, the channelized

185   portion of the Hikurangi Trench has the joint lowest axial gradient of all subduction trenches (av.

186   0.5˚). Axial channels occur in trenches across all of Earth's climate zones (Fig. 3).

187   **CONCLUSIONS**

188   Assessment of the bounding conditions of subduction trenches identifies the key controls

189   on the presence of a trench-axial channel to be the rate of terrigenous sediment supply and the

190   deposition of sufficient sediment cover to suppress trench rugosity. A sweet spot for axial

191   channel development may arise in the evolution of a trench, where it receives sufficient sediment

192   to develop an axial channel, but has not been overfilled to a point at which the channel may

193   escape the trench confines. Initially, terrigenous sediments entering a trench are spatially

194   restricted, compared with later dispersal of sediment along a trench by an axial channel. Hence,

195   simple models of trench fill are invalid in the presence of axial channels and their levees, which

196   regulate sediment distribution and promote lateral and longitudinal heterogeneity in trench fill.

197   The type, volume and timing of sediment deposited along a trench has implications for

198   the evolution of subduction zones, the type of material and fluids subducted and recycled by arc

199   volcanism, and the mechanical development of accretionary prisms. The presence of a trench-

200   axial channel results in a temporal and spatial variation in the sediment type being subducted and

201   its effects on plate boundary mechanics, the length scale of which will extend as a channel

202   propogates along a trench. Mapping the nature of trench sediments is therefore an important

203   consideration in modelling subduction deformation.

204   **ACKNOWLEDGMENTS**

REFERENCES CITED

209   Acocella, V., Spinks, K., Cole, J., and Nicol, A., 2003, Oblique back arc rifting of Taupo

210   Volcanic zone, New Zealand: Tectonics, v. 22.

211   Ballance, P.F., 1976, Evolution of the Upper Cenozoic magmatic arc and plate boundary in

212   northern New Zealand: Earth and planetary science letters, v. 28, p. 356–370.

213   Barnes, P.M., Wallace, L.M., Saffer, D.M., Bell, R.E., Underwood, M.B., Fagereng, A.,

214   Meneghini, F., Savage, H.M., Rabinowitz, H.S., Morgan, J.K., and Kitajima, H., 2020,

215   Slow slip source characterized by lithological and geometric heterogeneity: Science

216   Advances, v. 6, p.eaay3314.

217   Clift, P.D., MacLeod, C.J., Tappin, D.R., Wright, D.J., and Bloomer, S.H., 1998, Tectonic

218   controls on sedimentation and diagenesis in the Tonga Trench and forearc, southwest

219   Pacific: Geological Society of America Bulletin, v. 110, p. 483–496.

220   Ghisetti, F.C., Barnes, P.M., Ellis, S., Plaza-Faverola, A.A. and Barker, D.H., 2016, The last 2

221   Myr of accretionary wedge construction in the central Hikurangi margin (North Island, New

222   Zealand): Insights from structural modeling: Geochemistry, Geophysics, Geosystems, v. 17,

223   p.2661-2686.

224   Harris, P.T., Macmillan-Lawler, M., Rupp, J., and Baker, E.K., 2014, Geomorphology of the

225   oceans: Marine Geology, v. 352, p. 4–24.

226   Haywick, D.W., Carter, R.M., and Henderson, R.A., 1992, Sedimentology of 40 000 year

227   Milankovitch-controlled cyclothems from central Hawke's Bay, New Zealand:

228   Sedimentology, v. 39, p. 675–696.

229 von Huene, R., Langseth, M., Nasu, N., and Okada, H., 1982, A summary of Cenozoic tectonic

230   history along the IPOD Japan Trench transect: Geological Society of America Bulletin, v.

231   93, p. 829–846.

232 Jiao, R., Seward, D., Little, T.A., and Kohn, B.P., 2014, Thermal history and exhumation of

233   basement rocks from Mesozoic to Cenozoic subduction cycles, central North Island, New

234   Zealand: Tectonics, v. 33, p. 1920–1935, doi: 10.1002/2014TC003653.

235 Jiao, R., Herman, F., and Seward, D., 2017, Late Cenozoic exhumation model of New Zealand:

236   Impacts from tectonics and climate: Earth-Science Reviews, v. 166, p. 286–298, doi:

237   https://doi.org/10.1016/j.earscirev.2017.01.003.

238 Kane, I.A., Clare, M.A., Miramontes, E., Wogelius, R., Rothwell, J.J., Garreau, P., and Pohl, F.,

239   2020, Seafloor microplastic hotspots controlled by deep-sea circulation: Science, v. 368, p.

240   1140-1145.

241 Komar, P.D., 1973, Continuity of turbidity current flow and systematic variations in deep-sea

242   channel morphology: Geological Society of America Bulletin, v. 84, p. 3329–3338.

243 Kroeger, K.F., Crutchley, G.J., Kellett, R. and Barnes, P.M., 2019, A 3-D Model of Gas

244   Generation, Migration, and Gas Hydrate Formation at a Young Convergent Margin

245   (Hikurangi Margin, New Zealand): Geochemistry, Geophysics, Geosystems, v. 20, p.5126-

246   5147.

247 Lewis, K.B., 1994, The 1500-km-long Hikurangi Channel: trench-axis channel that escapes its

248   trench, crosses a plateau, and feeds a fan drift.: Geo-Marine Letters, v. 14, p.19-28.

249 Lewis, K.B., Collot, J.Y., and Lallemand, S.E., 1998, The dammed Hikurangi Trough: A

250   channel-fed trench blocked by subducting seamounts and their wake avalanches (New

251 Zealand-France GeodyNZ Project): Basin Research, v. 10, p. 441–468, doi: 10.1046/j.1365-

252 2117.1998.00080.x.

253 Lewis, S.D. and Hayes, D.E., 1984, A geophysical study of the Manila Trench, Luzon,

254 Philippines: 2. Fore arc basin structural and stratigraphic evolution: Journal of Geophysical

255 Research: Solid Earth, v. 89, p. 9196-9214.

256 McArthur, A.D., Claussmann, B., Bailleul, J., McCaffrey, W., and Clare, A., 2019, Variation in

257 syn-subduction sedimentation patterns from inner to outer portions of deep-water fold and

258 thrust belts: examples from the Hikurangi subduction margin of New Zealand: Geological

259 Society, London, Special Publications, v. 490, p. 285-310.

260 Moore, G.F. and Karig, D.E., 1976, Development of sedimentary basins on the lower trench

261 slope: Geology, v. 4, p. 693-697.

262 Moore, G.F., Curray, J.R., and Emmel, F.J., 1982a, Sedimentation in the Sunda Trench and

263 forearc region: Geological Society, London, Special Publications, v.10, p.245-258.

264 Moore, J.C., Watkins, J.S., McMillen, K.J., Bachman, S.B., Leggett, J.K., Lundberg, N., Shipley,

265 T.H., Stephan, J.F., Beghtel, F.W., Butt, A. and Didyk, B.M., 1982b. Facies belts of the

266 Middle America Trench and forearc region, southern Mexico: results from Leg 66

267 DSDP: Geological Society, London, Special Publications, v.10, p.77-94.

268 Mountjoy, J.J., Howarth, J.D., Orpin, A.R., Barnes, P.M., Bowden, D.A., Rowden, A.A.,

269 Schimel, A.C.G., Holden, C., Horgan, H.J., and Nodder, S.D., 2018, Earthquakes drive

270 large-scale submarine canyon development and sediment supply to deep-ocean basins:

271 Science advances, v. 4, p. eaar3748.

272 Ness, G.E., and Kulm, L.D., 1973, Origin and development of Surveyor deep-sea channel:

273 Geological Society of America Bulletin, v. 84, p. 3339–3354.

274   Nicol, A., Mazengarb, C., Chanier, F., Rait, G., Uruski, C., and Wallace, L., 2007, Tectonic

275   evolution of the active Hikurangi subduction margin, New Zealand, since the Oligocene:

276   Tectonics, v. 26, p. 1–24, doi: 10.1029/2006TC002090.

277   Omura, A., Ikehara, K., Arai, K., and others, 2017, Determining sources of deep-sea mud by

278   organic matter signatures in the Sunda trench and Aceh basin off Sumatra: Geo-Marine

279   Letters, v. 37, p. 549–559.

280   Polonia, A., Torelli, L., Mussoni, P., Gasperini, L., Artoni, A., and Klaeschen, D., 2011, The

281   Calabrian Arc subduction complex in the Ionian Sea: Regional architecture, active

282   deformation, and seismic hazard: Tectonics, v. 30, TC5018.

283   Rabinowitz, H.S., Savage, H.M., Skarbek, R.M., Ikari, M.J., Carpenter, B.M., and Collettini, C.,

284   2018, Frictional behavior of input sediments to the Hikurangi Trench, New Zealand:

285   Geochemistry, Geophysics, Geosystems, v. 19, p. 2973–2990.

286   Soh, W., Taira, A., and Tokuyama, H., 1988, A trench fan in the Izu-Ogasawara Trench on the

287   Boso Trench triple junction, Japan: Marine geology, v. 82, p. 235–249.

288   Thornburg, T.M., Kulm, L.D., and Hussong, D.M., 1990, Submarine-fan development in the

289   southern Chile Trench: a dynamic interplay of tectonics and sedimentation: Geological

290   Society of America Bulletin, v. 102, p. 1658–1680.

291   Tek, D.E., Poyatos-Moré, M., Patacci, M., McArthur, A.D., Colombera, L., Cullen, T.M. and

292   McCaffrey, W.D., 2020, Syndepositional tectonics and mass-transport deposits control

293   channelized, bathymetrically complex deep-water systems (Aínsa depocenter, Spain):

294   Journal of Sedimentary Research, v. 90, p. 729–762.

295   Tiffin, D.L., Davies, H.L., Honza, E., Lock, J., and Okuda, Y., 1987, The New Britain Trench

296   and 149 Embayment, western Solomon Sea: Geo-marine letters, v. 7, p. 135–142.

297   Tippett, J.M., and Kamp, P.J.J., 1993, Fission track analysis of the late Cenozoic vertical

298   kinematics of continental Pacific crust, South Island, New Zealand: Journal of Geophysical

299   Research: Solid Earth, v. 98, p. 16119–16148.

300   Underwood, M.B., and Bachman, S.B., 1982, Sedimentary facies associations within subduction

301   complexes: Geological Society, London, Special Publications, v. 10, p. 537–550.

302   Underwood, M.B., and Karig, D.E., 1980, Role of submarine canyons in trench and trench-slope

303   sedimentation: Geology, v. 8, p. 432–436.

304   Wallace, L.M. and Beavan, J., 2010, Diverse slow slip behavior at the Hikurangi subduction

305   margin, New Zealand: Journal of Geophysical Research: Solid Earth, v. 115, B12402.

306

307   **FIGURES**
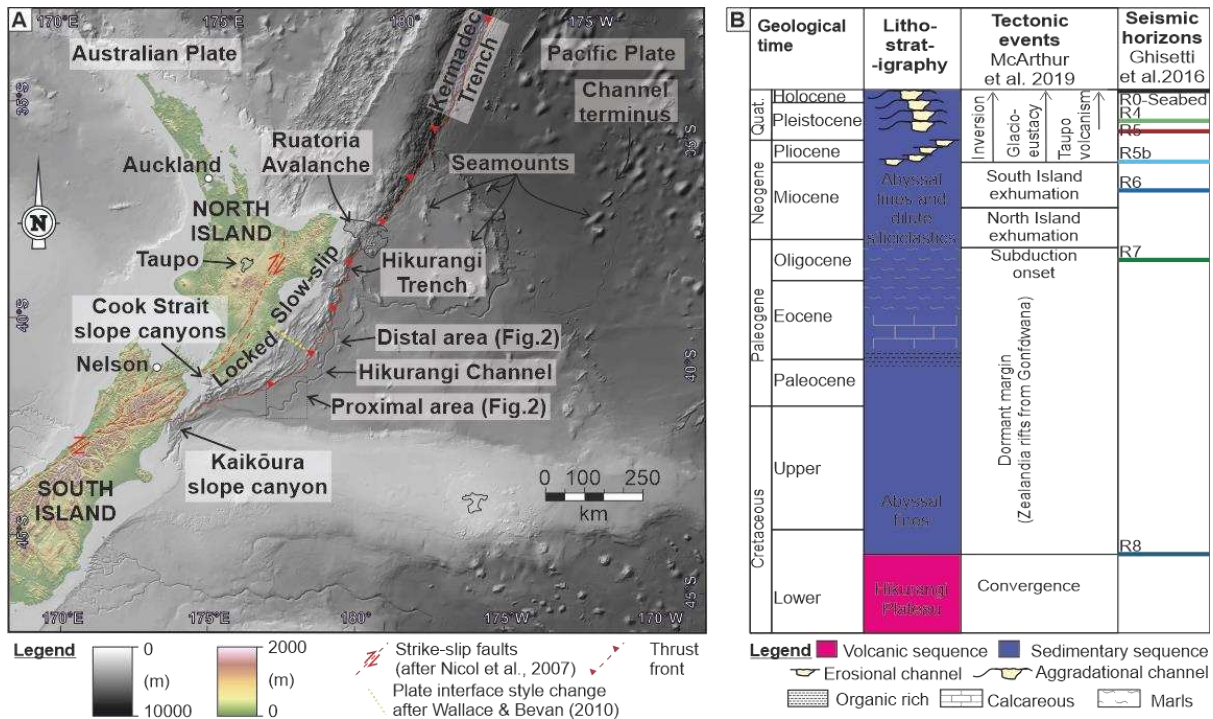
309   Figure 1. (A) Map of the Hikurangi Margin courtesy of NIWA. (B) Lithology and geological

310   history of the Hikurangi Trench.
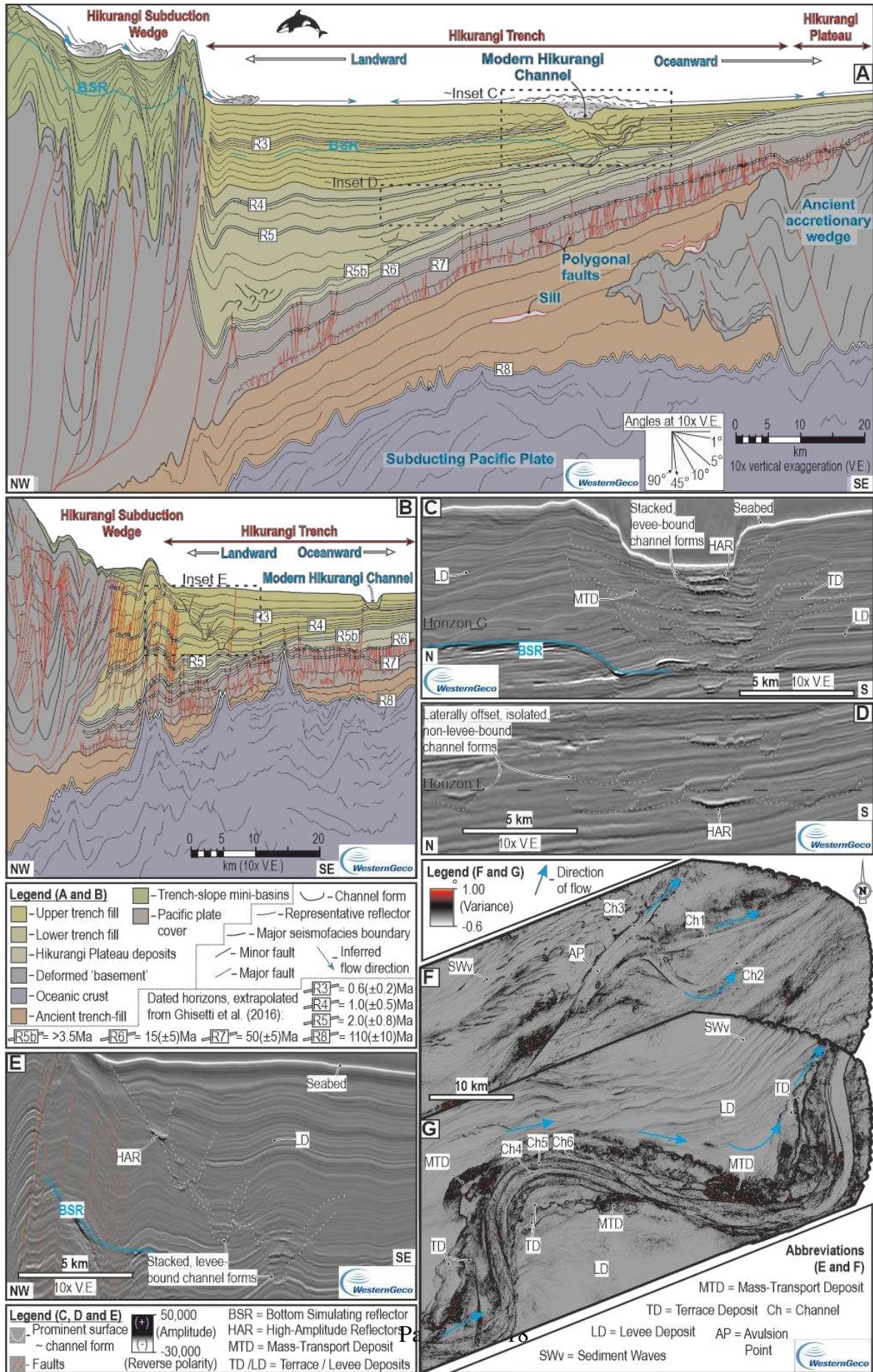
312   Figure 2. (A) Proximal and (B) distal interpreted depth sections of Hikurangi Trench fill

313   (uninterpreted data S3 and S4). (C) Enlargement of isolated channel fills from the proximal area

314   in the base of the trench fill. (D) Enlargement of upper ~800 m of the trench fill in the proximal

315   area. (E) Enlargement of upper ~800 m of the trench fill in the distal area. (F) Depth slice using

316   variance attribute analysis to illustrate the proximal, lower, isolated channel forms containing

317   relatively linear early channels (Ch1-3), which diverge through the trench fill. (G) Depth slice

318   using variance attribute analysis to illustrate the proximal, upper leveed channel form containing

319   channels Ch4-6.

320

321

322
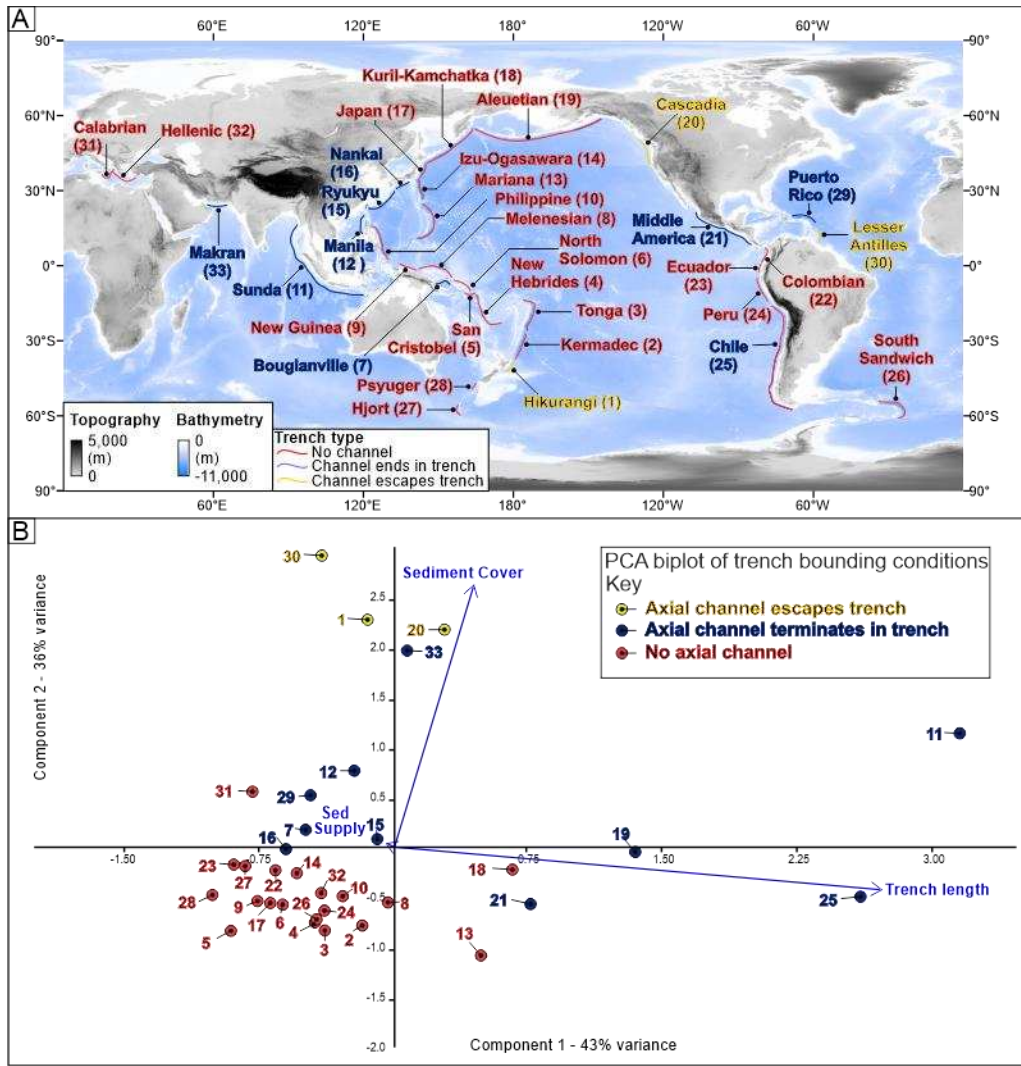
Figure 3. (A) Global distribution of subduction trenches and axial channels. (B) Principle

components analysis biplot (eigenvalue scale) of trench geomorphological factors. See S5 for

details of each trench and channel.
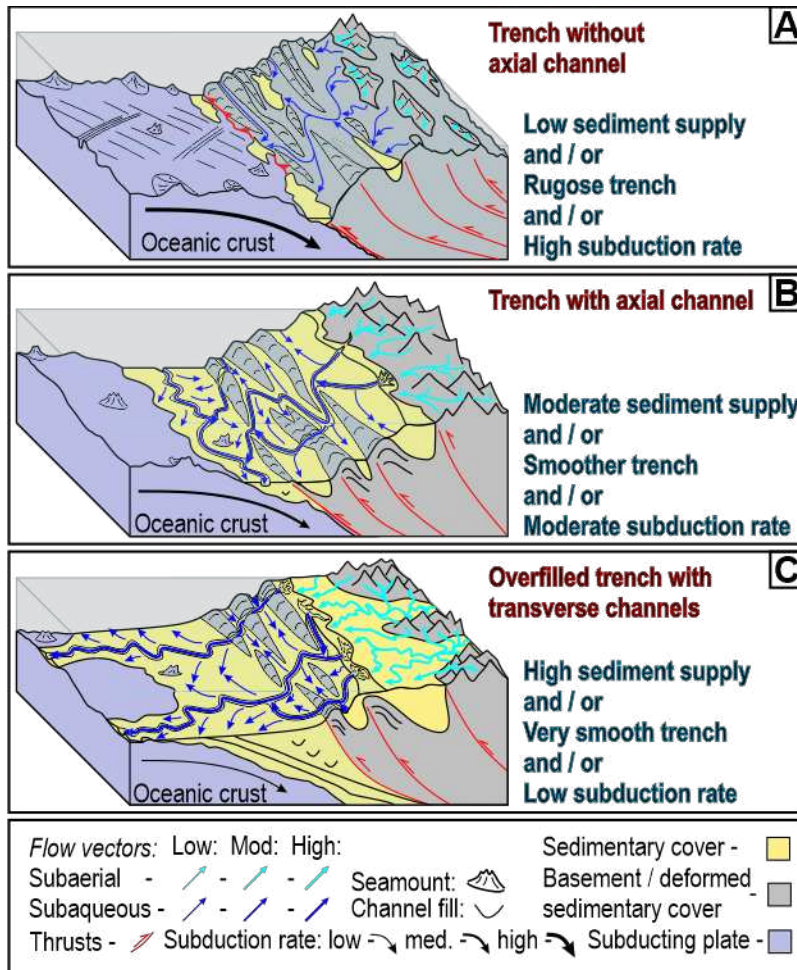
326

327   Figure 4. Schematic representation of controls on trench fill and axial channel evolution.