Physics of the Earth and Planetary Interiors 225 (2013) 12–27

Contents lists available at ScienceDirect

Physics of the Earth and Planetary Interiors

journal homepage: www.elsevier.com/locate/pepi

Along-strike variation in subducting plate seismicity and mantle wedge attenuation related to fluid release beneath the North Island, New Zealand

Donna Eberhart-Phillips [a,b,*], Martin Reyners [a], Manuele Faccenda [c], John Naliboff [b]

[a] GNS Science, PO Box 30368, Lower Hutt 5040, New Zealand
[b] Department of Earth and Planetary Sciences, University of California Davis, Davis, CA 95616, USA
[c] Department of Geoscience, University of Padua, 35131 Padua, Italy

ARTICLE INFO

Article history:
Received 9 November 2012
Received in revised form 3 October 2013
Accepted 7 October 2013
Available online 31 October 2013
Edited by G. Helffrich

Keywords:
Subduction
Slab seismicity
Dehydration
New Zealand
Volcanism

ABSTRACT

We analyze seismicity in the subducted slab of the Hikurangi subduction zone, along a 600-km length beneath the North Island, New Zealand. The volcanic character changes along strike with extremely productive rhyolitic volcanism in the central Taupo Volcanic Zone, moderate andesitic volcanism in the northern and south-central zones, and subduction without volcanism in the southernmost Hikurangi zone. We have relocated slab earthquakes with 3-D velocity models. The relocated seismicity shows more detail of the varied distribution and abundance of slab seismicity, which below 50-km depth may be related to embrittlement from high fluid pressure. The depth of the buoyant subducted Hikurangi Plateau ranges from 40 to 140 km depth.

At depths where the subducting slab interacts with the mantle wedge, along-arc variation in slab seismicity is a fundamental characteristic, with patches of abundant seismicity separated by low seismicity zones. The largest most numerous patch, at 150–220 km depth, underlies a pronounced low *Qp* zone in the mantle wedge, which is associated with the rhyolite-dominant Taupo caldera. Extensive melt in the region of low *Qp* requires high H_2O flux from the underlying slab. The abundant Taupo seismicity suggests a correlation between melt production and regions of earthquake fracture permeability following embrittlement which promote migration of dehydration fluid. The hydration history of the incoming slab may be a key factor in producing variations in dehydration and intraslab fluid migration. Broader, extensive outer-rise yielding and hydration may have occurred near the approach of the re-entrant Hikurangi Plateau, forming the slab section that currently has high seismicity. Slab seismicity deepens from 240 to 330 km along-arc as the subduction rate increases from <20 to >40 mm/yr. The southwestern slab seismicity is bounded by an unusually narrow zone with 110-km depth extent. This is inferred to be a dehydration front related to heating at a slab edge that is located 70 km further southwest.

1. Introduction

In this paper we examine along-arc variations in seismicity and seismic properties at depths greater than 50-km, where water from the slab dehydration interacts with the mantle wedge. In the North Island of New Zealand, the type of volcanism varies along the arc and the extent of volcanism is limited, as shown in Fig. 1. Andesitic volcanism started in the Taupo Volcanic Zone (TVZ) *ca.* 2 Myr ago, joined by voluminous rhyolitic (plus minor basaltic and dacitic) volcanism from *ca.* 1.6 Myr ago. Volcanic activity within the TVZ changes character along strike, with rhyolite-dominant caldera volcanoes in the central section and andesite dominant cone volcanoes to the north and south (Wilson et al., 1995). The modern central TVZ is the most frequently active and productive silicic volcanic system on Earth, erupting rhyolite at c. 0.28 m^3s^{-1}, and available information suggests this has been so for at least the past 0.34 Myr (Wilson et al., 1995). The average heat flux from the central 6000 km^2 of the TVZ is very high at 700 mW/m^2 (Bibby et al., 1995). The Taupo caldera is the primary rhyolitic producer and the Okataina volcanic center, located 80-km to the north, is also prolific. Volcanism in the TVZ ends at the andesitic Mt Ruapehu volcano, and further south the back arc is characterized by compression. Andesitic volcanism does occur in this region at Mt Taranaki, but this is about 130 km west of the volcanic front of the TVZ at Mt Ruapehu.

* Corresponding author at: Department of Earth and Planetary Sciences, University of California Davis, Davis, CA 95616, USA. Tel.: +1 530 771 7241.

E-mail addresses: eberhartphillips@ucdavis.edu (D. Eberhart-Phillips), m.reyners@gns.cri.nz (M. Reyners), manuele.faccenda@unipd.it (M. Faccenda), jbnaliboff@ucdavis.edu (J. Naliboff).

0031-9201/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.pepi.2013.10.002

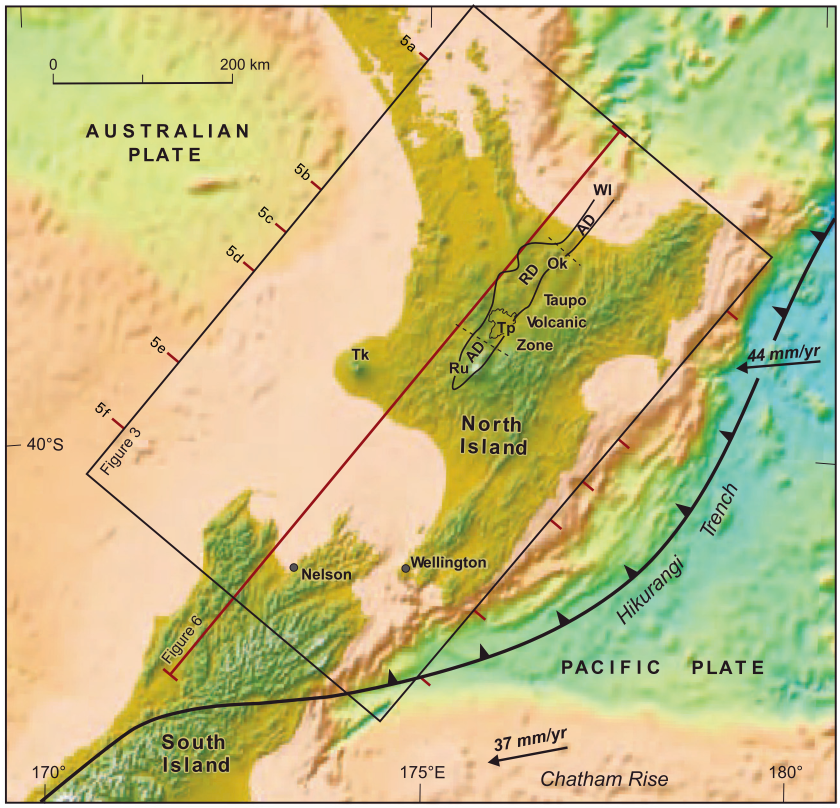

Fig. 1. Tectonic setting of the Hikurangi subduction zone in New Zealand. The arrows indicate the velocity of the Pacific plate relative to the Australian plate (DeMets et al., 2010). The Taupo Volcanic Zone is outlined and subdivided into three distinct segments: andesite dominant (AD) cone volcanoes in the northern and southern segments, and rhyolite dominant (RD) caldera volcanoes in the central segment (Wilson et al., 1995). The box outlines area shown in Fig. 3, and the red line indicates the extent of the depth section section in Fig. 6. Individual volcanoes discussed in the text are: Ok = Okataina; Ru = Ruapehu; Tk = Taranaki; Tp = Taupo; WI = White Island. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The 3-D *Qp* structure of the central North Island has been determined by Eberhart-Phillips et al. (2008). They find that the mantle wedge is generally imaged as a relatively low *Qp* (<400) feature below 50 km depth. However, there are significant changes evident in the wedge along the strike of the subduction zone. In the region of active volcanism, there is especially low *Qp* in the 50–125 km depth range, with *Qp* <250. The most pronounced low *Qp* in the mantle wedge occurs from *ca.* 50 to 85 km depth beneath the productive, rhyolite-dominated central segment of the TVZ, suggesting a close link between volcanism and low *Qp* in the shallow mantle wedge. Further southwest where the TVZ ends, the low *Qp* region in the mantle wedge terminates, in concert with regions of low *Vp* and high *Vp*/*Vs*. The *Vp* results of Reyners et al. (2006) suggest some additional low *Vp* mantle below Mt. Taranaki, although the *Qp* resolution is too weak in that region to confirm an anomaly there. In the central Andean subduction zone, using 3-D *Qp* studies, Schurr et al. (2003) have also inferred complex patterns of fluid and melt transport which vary along strike. They have shown that clusters of slab seismicity from 90 to 250 km depth are related to specific zones of slab dehydration and fluid release, which underlie distinct low *Qp* zones.

Dehydration of the subducted slab and sediment can produce water from 50 to 350 km depth which contributes to the subduction zone water cycle (Rupke et al., 2004; Iwamori, 2004). After dehydration, the produced water moves away and contributes to arc volcanism through H_2O-fluxed melting. Above the slab, a small amount of very H_2O-rich melt is produced which rises vertically and eventually produces a larger amount of lower H_2O% melt at the hot core of the mantle wedge (Grove et al., 2006). This process of removal of water is also influenced by solid flow in the mantle wedge, which needs to bring in requisite fertile material and to remove depleted material (Cagnioncle et al., 2007). While the processes can be understood by such 2-D petrological and numerical models, both surface volcanic distribution and mantle wedge tomography indicate along-arc variation. In Japan and Alaska there are regularly spaced volcanoes with corresponding volumes of melt-rich mantle inferred in the underlying mantle wedge (Nakajima et al., 2001; Hasegawa and Nakajima, 2004; Eberhart-Phillips et al., 2006).

Trenchward of the arc, properties of the stagnant mantle wedge corner have been used to infer dehydration of the underlying subducting slab. Kamiya and Kobayashi (2000) inferred serpentinized peridotite based on Poisson's ratio >0.3 (*Vp*/*Vs* >1.87), from 20 to 50 km depth in central Japan. Brocher et al. (2003) inferred serpentinized forearc mantle from low *Vp* (7.2–7.4 km/s) and seismic reflectivity, ranging from 30 to 50 km depth, along the Cascadia margin. Along the Hikurangi subduction zone, high *Vp*/*Vs* has also been imaged in the forearc at 30–40 km depth in the north and central sections, and at 50-km depth in the southern sections (Reyners et al., 1999, 2006; Eberhart-Phillips and Reyners, 2012). In the central Hikurangi subduction zone, Bannister et al. (2007) model receiver functions with a 10-km thick *Vs* 3.6 km/s layer above the 40-km depth plate interface, which appears as a thin layer to 55-km depth in a prestack migration, and is consistent with serpentinization of the forearc mantle wedge. At greater depth, Kawakatsu and Watada (2007) have imaged a thin low-velocity