

INTRAPLATE VOLCANISM OF THE WESTERN PACIFIC: NEW INSIGHTS
FROM GEOLOGICAL AND GEOPHYSICAL OBSERVATIONS IN THE
PIGAFETTA BASIN

By

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ABSTRACT

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Understanding intraplate volcanism is a key to deciphering the Earth's magmatic history. One of the largest intraplate volcanic events occurred during the mid Cretaceous, roughly 75 to 125 Ma in the western Pacific. To investigate the origin and effects of this volcanism on various Earth systems, we present the first comprehensive study of volcanism in the Pigafetta Basin using seismic surveys, magnetic and gravity modeling, and Ocean Drilling Program drill core and well log data from Site 801. Our results show that intraplate volcanism in the Pigafetta Basin coincides with the rest of the western Pacific, supporting the plumelets scenario for the origin of intraplate volcanism during the mid Cretaceous volcanic event. We also discover that the late stage volcanism does not overprint the original ocean crust in the Pigafetta Basin, and hence, marine magnetic anomalies recorded in the Jurassic basement are preserved. Also, the formerly identified Rough Smooth Boundary (RSB) is indistinguishable from any other rough-smooth topographic boundaries throughout the survey area suggesting that the RSB is unlikely to be a Cretaceous sill-Jurassic basement boundary. Lastly, the apparent ages and spatial distribution of volcanic features suggests a dynamic history of hydrothermal circulation in the Pigafetta Basin, indicating that hydrothermal circulation was ongoing well past 100 Ma.

ACKNOWLEDGMENTS

We thank the Japan Coast Guard Hydrographic and Oceanographic Department for seismic survey MTr5 data. Data from seismic surveys FM35-12 and MESOPAC II are publically available from the University of Texas Institute for Geophysics Academic Seismic Portal. Ocean Drilling Program Site 801 well logs and core information is publically available from the International Ocean Discovery Program Log database.

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KEY TO ABBREVIATIONS

ODP – Ocean Drilling Program

RSB – Rough Smooth Boundary

VSDZ – vertical seismic disturbance zone

MOR – mid ocean ridge

JQZ – Jurassic Quiet Zone

LAZ – Low amplitude zone

Ma – mega-annum, million years

mbsf – meters below sea floor

TWT – two way travel time

m – meters

km – kilometers

sec – seconds

msec - millisecond

MCS – multichannel seismic

in – inches

m/s – meters per second – unit of velocity

A/m – Ampere per meter – unit of Magnetic field strength

g/cm^3 – grams per cubic centimeter – unit of Density

g/API – grams per American Petroleum Institute units – measure of radioactivity in a rock

mGal – milliGal – unit of acceleration due to gravity

ohm m – ohm per meter – unit of resistivity

km/s – kilometers per second – unit of velocity

V_p – P-wave velocity

IGRF11 = International Geomagnetic Reference Field Model 2011

N – North

S – South

E – East

W – West

Ar – Argon

nT – nano Tesla – unit of magnetic field measurement

1. Introduction

Understanding intraplate volcanism is a key to deciphering the Earth's magmatic history. Intraplate volcanism has been globally observed in both terrestrial [e.g. *Morgan*, 1971; *Crisp*, 1984; *Nicholson and Shirey*, 1990] and marine settings [e.g. *Wilson*, 1963; *Wessel*, 1997; *Clouard and Bonneville*, 2001] and has been linked to a series of events throughout Earth's history including mass extinctions [*Rampino and Stothers*, 1988; *Stothers*, 1993], global sea level transgressions [*Schlanger et al.*, 1981], and oceanic anoxic events [*Jenkyns*, 1980; *Jones and Jenkyns*, 2001].

Seafloor, hosting global lithosphere-hydrosphere-atmosphere interactions, forms at mid ocean ridges (MOR's) and covers roughly 70 percent of the Earth's surface [*Showman and Dowling*, 2014]. The Pacific seafloor, covering approximately 50% of the world's ocean basins [e.g. *Longhurst*, 2007], is marked by numerous intraplate volcanic features such as large oceanic plateaus [e.g. *Coffin and Eldholm*, 1994], seamounts [e.g. *Menard*, 1964; *Heezen et al.*, 1973], and deep-sea sills/flows [e.g. *Larson and Schlanger*, 1981; *Schlanger and Moberly*, 1986]. Volcanic activity and crustal emplacement mechanisms, including seamounts, at on- and off-axis regions of MORs have been extensively studied [e.g. *Hess*, 1962; *Vine*, 1966; *Haymon et al.*, 1991; *Haymon et al.*, 1993; *Carbotte et al.*, 1994; *Hoofst et al.*, 1996; *Fornari et al.*, 1998; *Curewitz and Karson*, 1998; *Chadwick and Embley*, 1998;]; however, the origin and implications of intraplate volcanism is in debate because of the great extent of these volcanic features [cf. *Larson and Schlanger*, 1981; *McNutt et al.*, 1990; *Wessel*, 1997; *Koppers et al.*, 2001; *Koppers et al.*, 2003a, *Korenaga*, 2005].

The Pigafetta Basin, one of the oldest portions of the Pacific plate, is a NW-SE trending deep-sea basin located approximately 700 km east of the Mariana Trench in the western Pacific

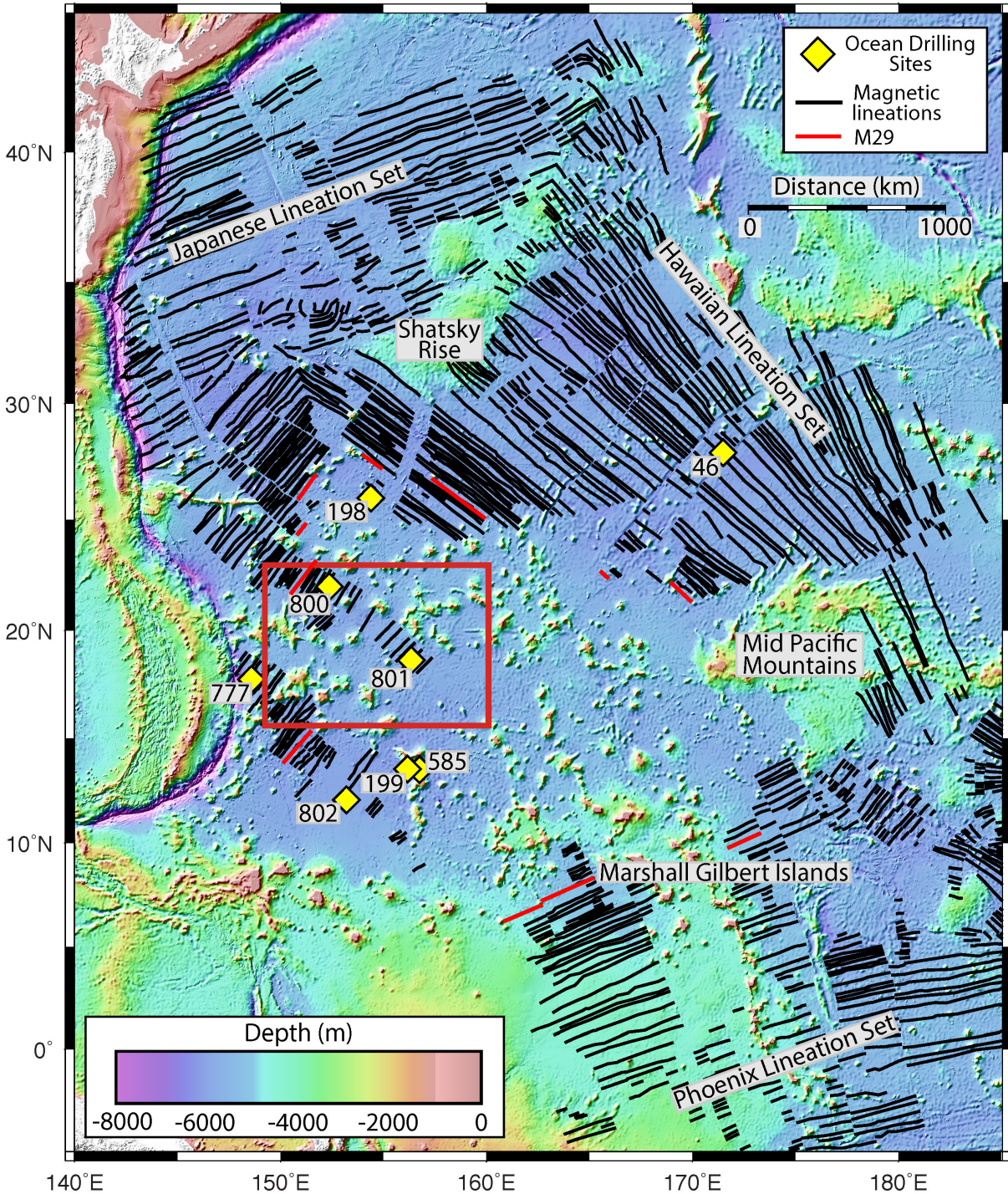


Figure 1: Map of western Pacific with study area outlined in red box. Magnetic lineations drawn in black from Nakanishi *et al.*, [1992] and Tominaga *et al.*, [2008]. Ocean drilling sites indicated by yellow diamonds (ODP and DSDP Sites). Major features labeled to provide geography of the region. Bathymetry data is from Ryan *et al.*, [2009].

Ocean (Figure 1). The Pigafetta Basin has a nominal water depth of ~5800 m and is marked by Mesozoic sequence Japanese magnetic lineations [e.g. Handschumacher *et al.*, 1988; Nakanishi

et al., 1989] where Chron M42 has been dated at 167 Ma [Pringle, 1992; Koppers *et al.*, 2003b]. Although surrounded by the Marcus-Wake and Magellan Seamount chains as a result of Cretaceous supervolcanism [i.e. Larson, 1991], seafloor in the Pigafetta Basin appears to be little disturbed by the Cretaceous volcanism, allowing the basin to be extensively used as a corridor for research on the early history of Pacific plate evolution.

Over the past few decades, a series of research efforts, including seismic surveys [Ewing *et al.*, 1968; Abrams *et al.*, 1992, 1993], marine magnetic surveys [Handschumacher *et al.*, 1988; Sager *et al.*, 1998; Tivey *et al.*, 2006; Tominaga *et al.*, 2008], and Ocean Drilling Program (ODP) Legs (129 and 185), [Lancelot *et al.*, 1990b, Plank *et al.*, 2000] have investigated the formation and evolution of the Pigafetta Basin. Despite these efforts, an important line of observations has been lacking to understand the origin of late-stage volcanism that shaped the Pigafetta Basin, its effects on the original Jurassic seafloor, and its implications on intraplate volcanism in the western Pacific.

To address these questions, we carried out a detailed, systematic investigation of volcanic features in the Pigafetta Basin by integrating three multichannel seismic reflection survey datasets, drill core and wireline logging data from ODP Site 801, satellite gravity data, and sea surface level magnetic anomalies.

2. Background

2.1. Tectonic and volcanic history of the Pacific plate

The Pacific plate was formed at the Phoenix-Izanagi-Farallon triple junction in the Mid Jurassic (175 - 180 Ma) as a consequence of the break up of the last supercontinent Pangaea [Nakanishi *et al.*, 1989; Coffin *et al.*, 2000; Bartolini and Larson, 2001]. Three magnetic lineation sets, the Japanese, Hawaiian, and Phoenix, outline this early tectonic evolution of the Pacific plate as it expanded from the triple junction system and moved northwards to its present location (Figure 1) [Larson and Chase, 1972; Hilde *et al.*, 1976; Woods and Davies, 1982; Nakanishi *et al.*, 1992]. Chron M29 [Cande *et al.*, 1978; Kent and Gradstein, 1985; Channell *et al.*, 1995], currently dated at 157 Ma [Gradstein *et al.*, 1994, 2012], is the oldest, widely accepted coherent magnetic lineation in all three lineation sets of the western Pacific (Figure 1). Prior to Chron M29, the validity of magnetic anomalies remains in debate due to the Jurassic Magnetic Quiet Zone (JQZ), a region of ocean crust with low amplitude, short wavelength, difficult to correlate magnetic anomalies [Heirtzler and Hayes, 1967; Taylor *et al.*, 1968; Emery *et al.*, 1970; Larson and Pitman, 1972; Hayes and Rabinowitz, 1975; Barrett and Keen, 1976; Hilde *et al.*, 1976; Cande *et al.*, 1978; Handschumacher *et al.*, 1988; Sager *et al.*, 1998; Tivey *et al.*, 2006; Tominaga *et al.*, 2008].

Widespread intra-plate volcanic features mark the western Pacific seafloor, including the Mid Pacific Mountains [e.g. Hamilton, 1956], Marshall-Gilbert Islands [e.g. Morgan, 1972], Magellan Seamounts [e.g. Smith *et al.*, 1989], and Marcus-Wake Seamounts [Heezen *et al.*, 1973] (Figure 1). The style of magmatism that emplaced these widespread volcanic features has been extensively discussed. The nonsystematic spatial and age distributions [e.g. Larson, 1991; Winterer *et al.*, 1993; Koppers *et al.*, 2003a] of these volcanic features suggest the existence of a

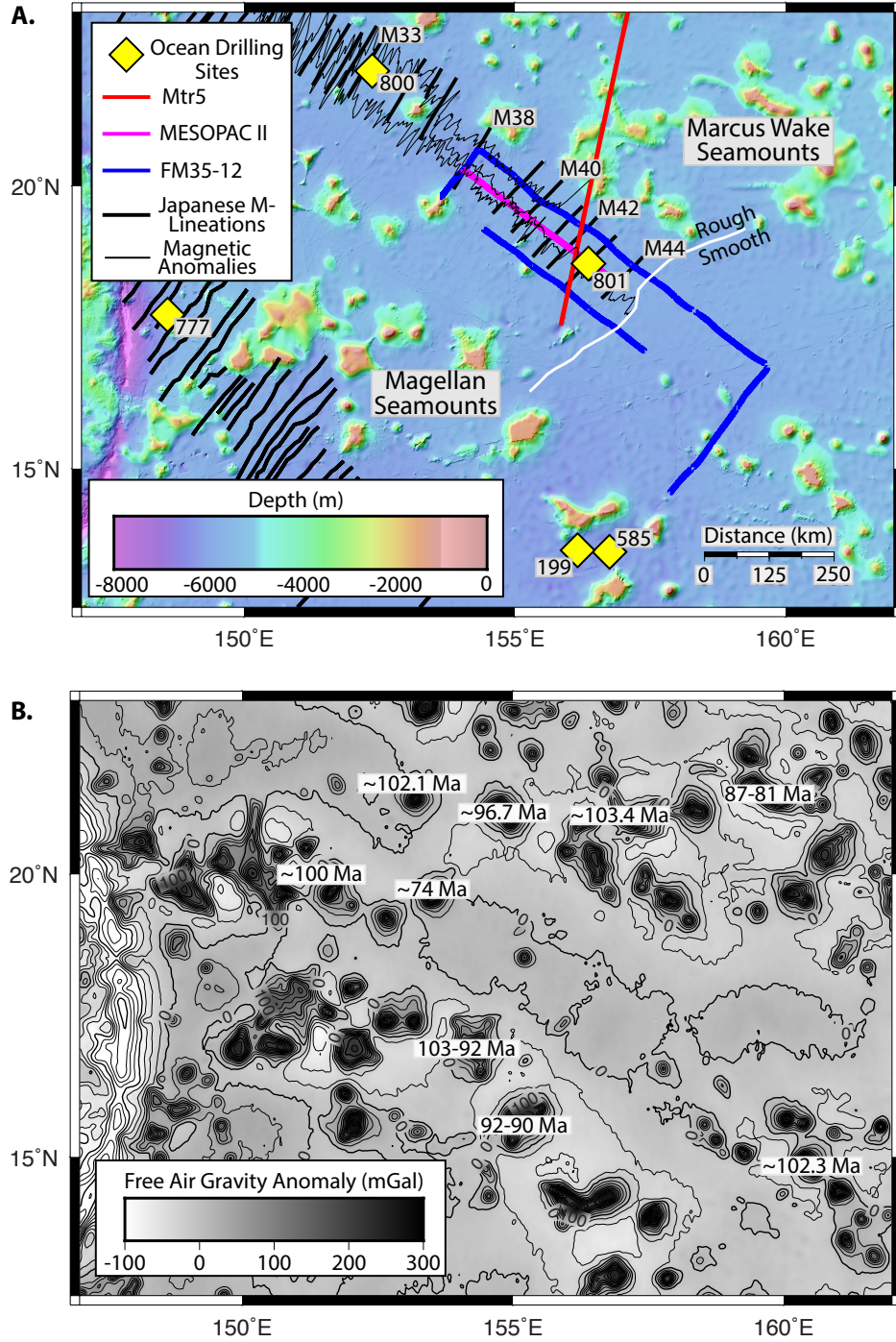


Figure 2: Map of the Pigafetta Basin. **A.** Bathymetry map of the Pigafetta Basin showing seismic surveys, magnetic anomalies, magnetic lineations, ODP Site 801, and location of Rough Smooth Boundary (RSB). **B.** Free air gravity map of Pigafetta Basin with 10 mGal contours and radiometric age dates of seamounts. Seamount age data from Ozima *et al.*, [1983] and Koppers *et al.*, [2003a], bathymetry from Ryan *et al.*, [2009], gravity data from Sandwell *et al.*, [2014 grid v. 23.1].

contemporaneous volumetrically large magma source under the western Pacific. Absolute $^{40}\text{Ar}/^{39}\text{Ar}$ dating of seamounts in the Marcus-Wake and Magellan Seamount chains yields ages

ranging from 75-125 Ma [e.g. *Ozima et al.*, 1984; *Clouard and Bonneville*, 2004]. The Pigafetta Basin, compared to the surrounding seamount provinces, however, shows minimal volcanic features on its seafloor. Previous studies have suggested that late stage volcanic features dominantly emerge as deep-sea sills and flows in this basin [*Abrams et al.*, 1993].

The numerous intraplate volcanic features in the western Pacific have casted a shadow on the authenticity of the geological signature recorded within the original Jurassic seafloor and therefore on the JQZ magnetic anomalies [*Kent and Gradstein*, 1985; *Lancelot et al.*, 1990; *Tominaga et al.*, 2008]. In the Pigafetta Basin, continued research on marine magnetic anomalies using high-resolution, near source survey approaches have provided correlatable low amplitude anomalies back to M44 (~170 Ma) [*Sager et al.*, 1998; *Tivey et al.*, 2006; *Tominaga et al.*, 2008]. A region of extremely low amplitude anomalies, namely the Low Amplitude Zone (LAZ) [*Tivey et al.*, 2006; *Tominaga et al.*, 2008], was revealed in the course of their effort. Whether the anomalies in the JQZ and LAZ are of geomagnetic field origin or Cretaceous volcanic overprint remains in debate [*Kent and Gradstein*, 1985; *Lancelot et al.*, 1990; *Tominaga et al.*, 2008].

2.2 Ocean Drilling Results

ODP Hole 801C is located at 18° 38.538'N 156° 21.588'E in the Pigafetta Basin (Figure 2). Drilling and coring was initiated during ODP Leg 129 [*Lancelot et al.*, 1990a; *Lancelot et al.*, 1990b] and deepened during ODP Leg 185 [*Plank et al.*, 2000]. A total of 461.6 and 474 m of sediment and basement sequences were cored, respectively, providing details about sedimentation history [*Behl and Smith*, 1992; *Karpoff*, 1992; *Ogg et al.*, 1992], basement ages [*Pringle*, 1992], and ocean crust formation and evolution [*Castillo et al.*, 1992; *Floyd and Castillo*, 1992; *Alt and Teagle*, 1999]. Core samples at 801C from ODP Leg 185 yielded high-

resolution $^{40}\text{Ar}/^{39}\text{Ar}$ dating of basement rocks at Hole 801C ($167.4 \pm 1.4/3.4$ Ma, internal/absolute error) [Koppers *et al.* 2003b].

Wireline logging operations at Hole 801B and 801C were conducted during ODP Legs 129, 144 and 185 (Figure 3) [Lancelot *et al.*, 1990b; Premoli Silva *et al.*, 1993; Plank *et al.*, 2000]. The logging data covers from ~60 - 450 meters below sea floor (mbsf) and ~470 – 850 mbsf but does not cover the sediment-basement interface. Downhole lithofacies analyses documented the crustal formation at a fast spreading ridge [Pockalny and Larson, 2003], and revealed multiple magnetic reversals in the oceanic basement, suggesting a scenario that the low anomaly amplitudes in the JQZ can be attributed to the superposition of oppositely magnetized blocks, canceling directional magnetic signals [Steiner, 2001; Tivey *et al.*, 2005].

2.3 Seismic Surveys of the Pigafetta Basin

The western Pacific sub-seafloor is composed of mainly red clay, siliceous oozes (chert and radiolarite), volcanoclastic sediments, and volcanic basement [e.g. Winterer *et al.*, 1971b; Lancelot *et al.*, 1990b]. Stratigraphy was established by a series of drilling expeditions [Heezen *et al.*, 1969a; Heezen *et al.*, 1969b; Winterer *et al.*, 1969; Winterer *et al.*, 1971a; Winterer *et al.*, 1971b; Heezen *et al.*, 1971a; Heezen *et al.*, 1971b] and coring and logging results from Site 801 [Lancelot *et al.*, 1990b] that ground-truthed early seismic surveys in the western Pacific [Ewing *et al.*, 1968]: (1) an upper transparent unit (to frequencies of 60-120Hz) (weakly reflective) corresponding to pelagic clay, (2) an upper opaque layer (highly reflective and/or well stratified) corresponding to chert, (3) a lower transparent layer corresponding to volcanoclastic turbidites and radiolarite, and (4) basement (rough acoustic basement surface) corresponding to Jurassic to early Cretaceous age ocean crust.

The seismic stratigraphy of the Pigafetta Basin was further confirmed by two active source seismic surveys, FM35-12 and MESOPAC II. *Abrams et al.* [1993] used profiles from both surveys to map the extent of a volcanic sequence termed “Horizon B”. This reflector covers much of the Pigafetta Basin and was interpreted to be Cretaceous sills overlying Jurassic basement. They also pointed out a distinct change in acoustic basement topography, termed the Rough Smooth Boundary (RSB) that may coincide with the edge of mid-Cretaceous sills in the southeast Pigafetta Basin (Figure 2).

The Japan Coast Guard Hydrographic and Oceanographic Department conducted a seismic reflection and refraction survey, MTr5, in the Pigafetta Basin in 2006 (Figure 2a) [*Kaneda et al.* 2010]. The MTr5 survey line extends from the Pigafetta Basin to two Marcus-Wake seamounts providing a velocity model of the crust and suggesting a constant crustal thickness of 7.5 – 8 km in the Pigafetta Basin.

Survey Name Year Acquired	Survey Length	V/H Resolution	Distance from Hole 801	Source Size	Receiver Length	No. of channels
FM35-12 1987	>1500 km	25 m/ 25 m	50 and 70 km to N and S	Various Airguns 40.65 L volume average	3200 m	96
MESOPAC II 1989	~ 400 km	10 m/ 10 m	< 3 km N	4 to 6 1.3 L waterguns 2 16 L airguns	undoc	96
Mtr5 2006	~ 250 km	10 m/ 10 m	~ 25 km W	36 airguns, 132 L total volume	6000 m	480

Table 1: Available data processing and acquisition parameters from *Abrams et al.* [1992], [1993], *Kaneda et al.* [2010], and *Shipley et al.* [2012]

3. Methods

3.1 Seismic Data

To document volcanic features in the Pigafetta basin on a basinwide scale, we used 2D multichannel seismic (MCS) reflection profiles from three surveys focusing on the region around ODP Hole 801C (Figure 2): FM35-12, MESOPAC II [Shipley, 2012], and MTr5 [Kaneda *et al.*, 2010]. We used approximately 1500 km of profiles from survey FM35-12 outlining the edge of the study area. We used one profile, approximately 400 km long, from MESOPAC II, which crosses within 3 km of Hole 801C and intersects FM35-12 Line 11 at its northwest end. We also used an approximately 250 km long profile from the southern end of MTr5 line, which intersects FM35-12 profiles in two locations and MESOPAC II near Hole 801C (Figure 2). Although each survey used different acquisition systems and data processing schemes, we could use the data because our primary objective, to characterize volcanic features, was not hindered by any of the survey parameters (Table 1).

3.2 Seismic Interpretation

To display the seismic lines for our interpretation, we used OpendTect v.4.6.0 software. First, we generated a synthetic seismogram from ODP Hole 801C density (g/cm^3) and P-wave velocity (km/s) logs. Next, we correlated traces from the synthetic seismogram to acoustic reflectors where the MESOPAC II survey line crosses the ODP Hole 801C location, and extrapolated the correlation across the MESOPAC II profile (Figure 4b). Lastly, we extrapolated the interpretation to MTr5 and FM35-12 survey profiles using the log-reflector correlation where the lines intersected with the MESOPAC II survey (Figure 2).

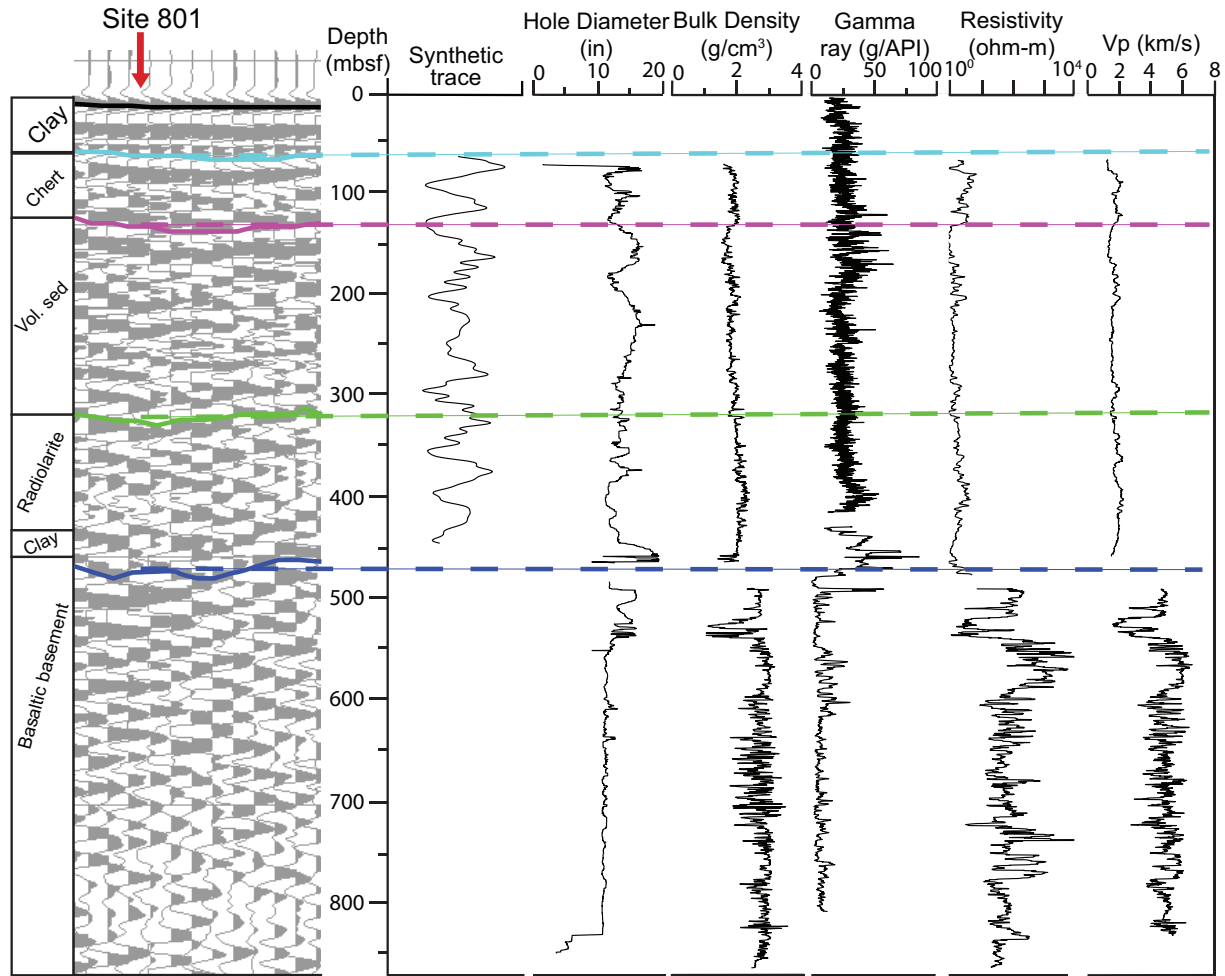


Figure 3: Summary of seismic stratigraphy at Site 801 showing correlations from MESOPAC II line with synthetic seismogram, unit thicknesses, and well logs. Dashed lines show correlation, cyan line corresponds to clay, chert boundary, and magenta line corresponds to chert, volcaniclastic boundary. Green line corresponds to volcaniclastic, radiolarite boundary, and blue corresponds to sediment, basement interface. This correlation was basis for seismic interpretation of Pigafetta Basin. Logging data taken from ODP well log database. Logs taken in upper 450 m from Leg 129 Hole 801B, and logs taken in lower 450 m from Leg 185 Hole 801C.

We assigned ages to sedimentary reflectors using biostratigraphic and radiometric ages recovered from Hole 801C core data [Lancelot *et al.*, 1990b]: an age of 72 Ma (Campanian-Maastrichtian boundary) to the top of the upper opaque unit (chert horizon); an age of 93.9 Ma to the top of the upper transparent unit; and an age of 113 Ma to the top of the lower transparent unit. Basement age at Hole 801C is ~167.5 Ma [Koppers *et al.*, 2003b].

We mapped inferred Horizon B-Jurassic basement boundaries based on *Abrams et al.* [1993] interpretation to be consistent with refraction data, and accepted a middle Cretaceous age to Horizon B (assigned by *Abrams et al.* [1993]).

In addition to the seafloor, major sedimentary unit reflectors, and acoustic basement, we identified three types of volcanic features: seamounts, vertical seismic disturbance zones (VSDZs), and sills. We assigned an apparent age to each volcanic feature based on their crosscutting relationships with the sedimentary reflectors with assigned ages as described above. We determined the height of seamounts from the seafloor, converting the difference in travel time to meters by using a constant velocity of 1500 m/s in the water column. We determined the width of features by calculating the distance in between each trace in the profile. We determined the height of VSDZs by measuring the distance from acoustic basement to the top of the feature in the sediment packet, assigning a constant velocity to the sediment packet of 2 km/s from *Abrams et al.* [1992], and Hole 801B and 801C data [*Lancelot et al.*, 1990b].

3.3 Gravity model

To obtain a model of crustal structure and depth to Moho in the Pigafetta Basin, we conducted forward gravity modeling along each seismic line (Figure 4). We extracted observed gravity profiles from the global satellite gravity anomaly map by *Sandwell et al.* [2014] v. 23.1. We exported horizons from our seismic lines to constrain the upper crust and sedimentary sequence thicknesses. Only survey MTr5 imaged the Moho (Figure 4a), allowing us to place a plausible estimate on the depth (~13.5 km) and topography of the Moho throughout the other two seismic survey profiles.

Modeled gravity anomalies were calculated using *Parker* [1973] Fourier transformation approach. We assigned densities and thickness of layers from Hole 801C data and a crustal density of 2.67 g/cm^3 [e.g. *Oikawa and Kaneda*, 2007] and 3.3 g/cm^3 for the upper mantle [Kaneda et al., 2010]. We assigned a constant density for layer 2 and 3 because: (1) the layer 2/3 boundary is unclear in the Pigafetta Basin (seismic velocity analysis from *Kaneda et al.*, [2010] and predictions based on spreading rate by *Purdy et al.*, [1992] disagree by $> 1 \text{ km}$), and (2) a density contrast between upper and lower crust in the Pigafetta Basin creates unreasonable anomalies and geologic implications that do not match similar gravity models [e.g. *Contreras-Reyes et al.*, 2010] (see Appendix Figure 1). A 4 km Gaussian filter was applied to smooth the data before adjusting layer structure and thickness.

3.4 Magnetic model

To assess the effect of late stage volcanic overprint on in situ magnetization in the Jurassic basement, we conducted forward magnetic modeling based on *Parker* [1973] Fourier transformation approach. We first created a crustal model with three layers; Layer 1 - sediments, Layer 2 – extrusive basalts, and Layer 3 – sheeted dikes, with magnetizations of 0.5 A/m, 2.0 to -2.0 A/m, and 1.0 A/m respectively [e.g. *Pariso and Johnson*, 1991] (Figure 8). We assigned a thickness of 0.5 km for sediments, similar to Pigafetta Basin sediment thickness, 1.0 km for Layer 2, and 1.0 km for Layer 3. We assigned a thickness of 1.0 km and magnetizations ranging from 2.0 to -2.0 A/m for Layer 2 (the highly magnetized layer) [*Sager et al.*, 1998; *Tominaga et al.*, 2008] (Figure 4b). We also assigned the paleo inclination and declination values based on *Larson and Sager* [1992] and today's inclination and declination values from IGRF11 model to properly calculate skewed magnetic anomalies observable in the Pigafetta Basin. We used

polarity reversal block models with vertical polarity boundaries, at intervals of < 5 km up to 60 km. We emplaced VSDZs and sills extending from Layer 2 into the sedimentary layer and assigned widths of 10 km to 80 m that are consistent with the dimensions of features we documented in the seismic profiles in the Pigafetta Basin (Figure 8). An 8 km Gaussian filter was applied to smooth the edge effects at the each polarity boundary.

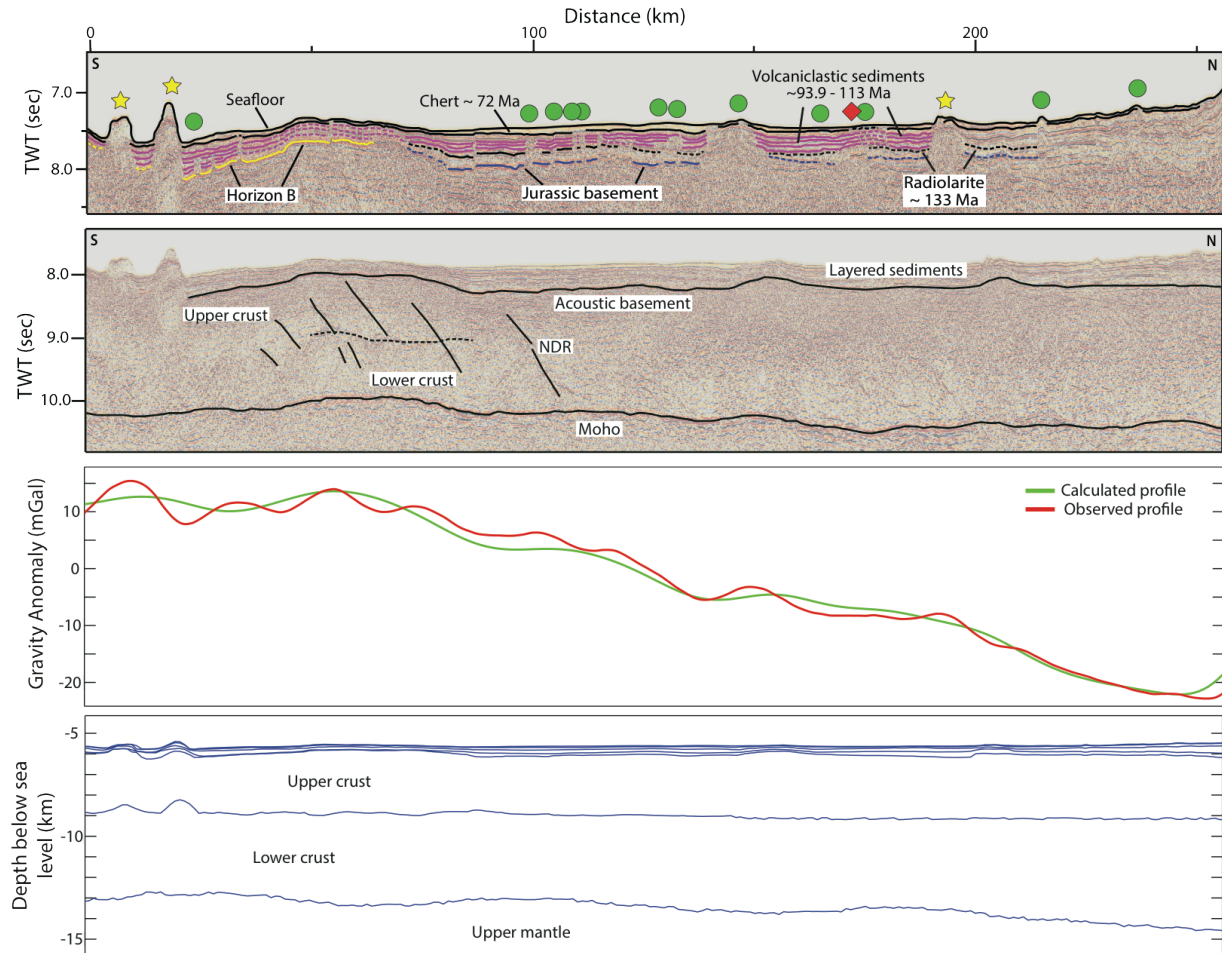


Figure 4a: MTr5. From top to bottom: First panel shows seismic interpretation of survey MTr5 line showing locations of volcanic features (yellow star – seamount, green circle – VSDZ, red diamond – sill). Second shows interpretation of oceanic crust from Kaneda et al., [2010] which we used for placing a plausible estimate on Moho depth in the Pigafetta Basin. Third panel shows comparison of observed versus modeled gravity profile over line MTr5, and the bottom panel shows our model of crustal structure beneath MTr5 in the Pigafetta Basin.

4. Results

4.1 Volcanic features

We documented coherently observed volcanic features throughout all three seismic surveys in the Pigafetta Basin and categorized these features into three groups based on their acoustic attributes: (1) vertical seismic disturbance zones (VSDZs), (2) seamounts and (3) sills. A total of 55 volcanic features were identified, including 35 VSDZs, 17 seamounts, and 3 sills (Table 2, Figure 6a).

We identified VSDZs as features that crosscut acoustic basement and are confined to the subsurface with little effect (<50 m) on seafloor topography (Figure 4). Upward drag on both edges and/or onlap of adjacent reflectors was also noted as attributes of VSDZs. Apparent ages of VSDZs range from 72-113 Ma (Figure 6d), and apparent heights of VSDZs range from 165 to 435 m (Figure 6b). In survey MTr5 VSDZs were traced > 1 km into basement.

We classify a seamount as a vertically continuous seismic disturbance zone with a topographic expression greater than 50 m above the seafloor (to match global data sets [i.e. *Smith and Cann*, 1990; *Wessel et al.*, 2010]). Seamounts are marked by upward drag on both edges and/or onlap and crosscutting of adjacent reflectors. A total of 17 seamounts were covered in the survey lines (Figures 5, 6a, and Table 2). Apparent ages range from 72-113 Ma (Fig. 6d).

Seamount heights range from 55 to 1600 m above the seafloor (one exception > 5000 m, named Grand Pacific Seamount) (Figure 6c). A size-frequency distribution plot of seamounts in the Pigafetta Basin appears to follow the power law relationship (Figure 7).

Sills are in general identified as saucer shape to flat, high amplitude, highly reflective intra-sediment horizons flanked by a VSDZ on one or both sides [*Planke et al.*, 2005; *Hanson and Cartwright*, 2006; *Polteau et al.*, 2008] while having little or no effect on seafloor topography.

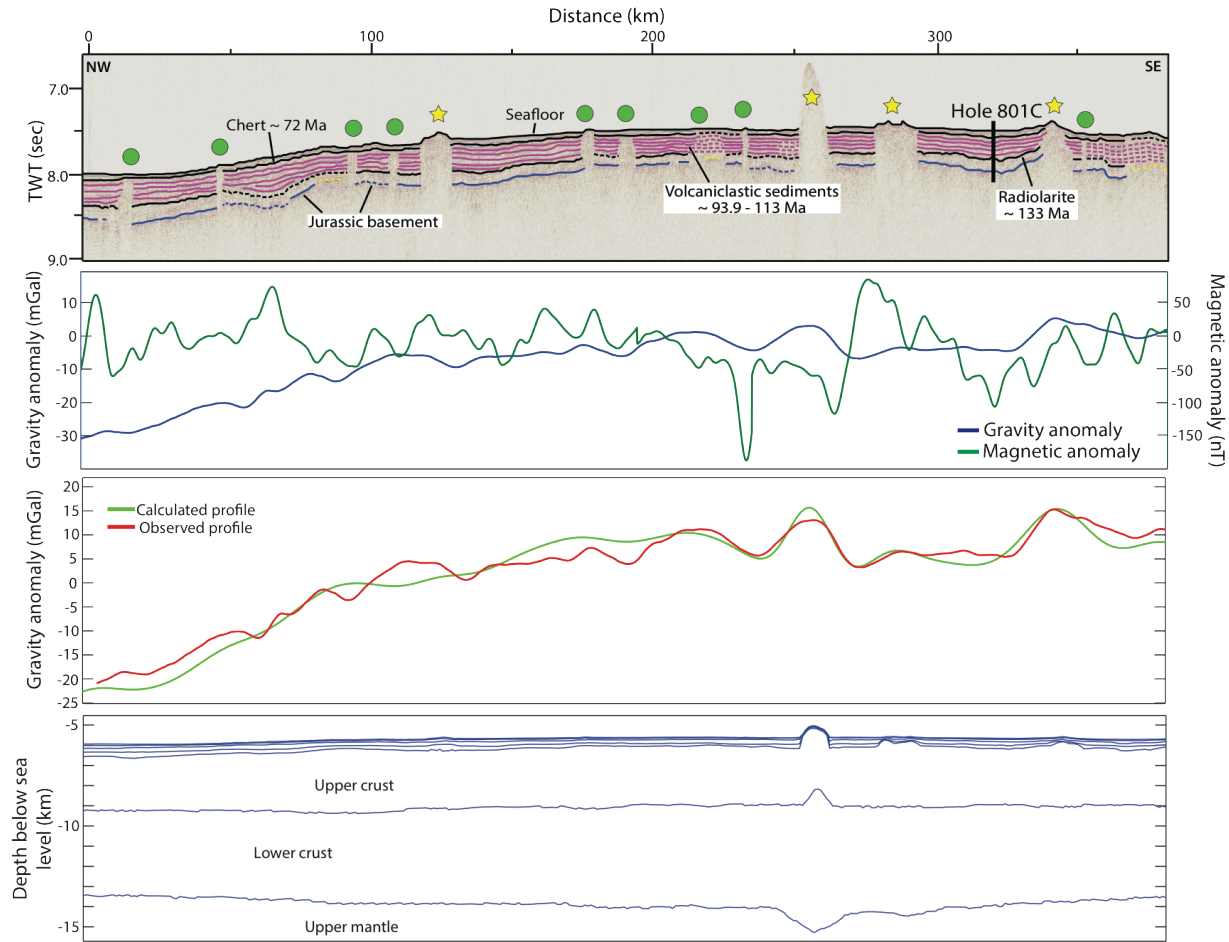


Figure 4b: MESOPAC II Line. From top to bottom: First panel shows seismic interpretation of MESOPAC II seismic data profile showing locations of volcanic features (yellow star – seamount, green circle – VSDZ, red diamond – sill). Next panel shows correlation between magnetic anomaly profile and gravity profile over MESOPAC II Line. Third panel shows comparison of observed versus modeled gravity profile and the bottom panel shows modeled crustal structure beneath MESOPAC II survey line. Magnetic anomaly profile is upward continued to the sea surface from 2002 mid tow survey [Tominaga *et al.*, 2008].

We note three sills in our seismic profiles, apparent ages range from 93.9-113 Ma. Widths of the sills range from 3 to 12 km (Table 2), and up-dip (~100 msec) is observed across horizons in FM35-12 survey lines.

Apparent ages of these volcanic features in the Pigafetta basin range from 72-113 Ma (Figure 6d), and the age distribution map (Figure 5a) shows no clear age linearity or progressions on a basin wide scale. Spatial distribution of the features in the Pigafetta Basin appears to be also nonsystematic (Figure 5a), showing no clear coherent pattern on a basin wide scale.

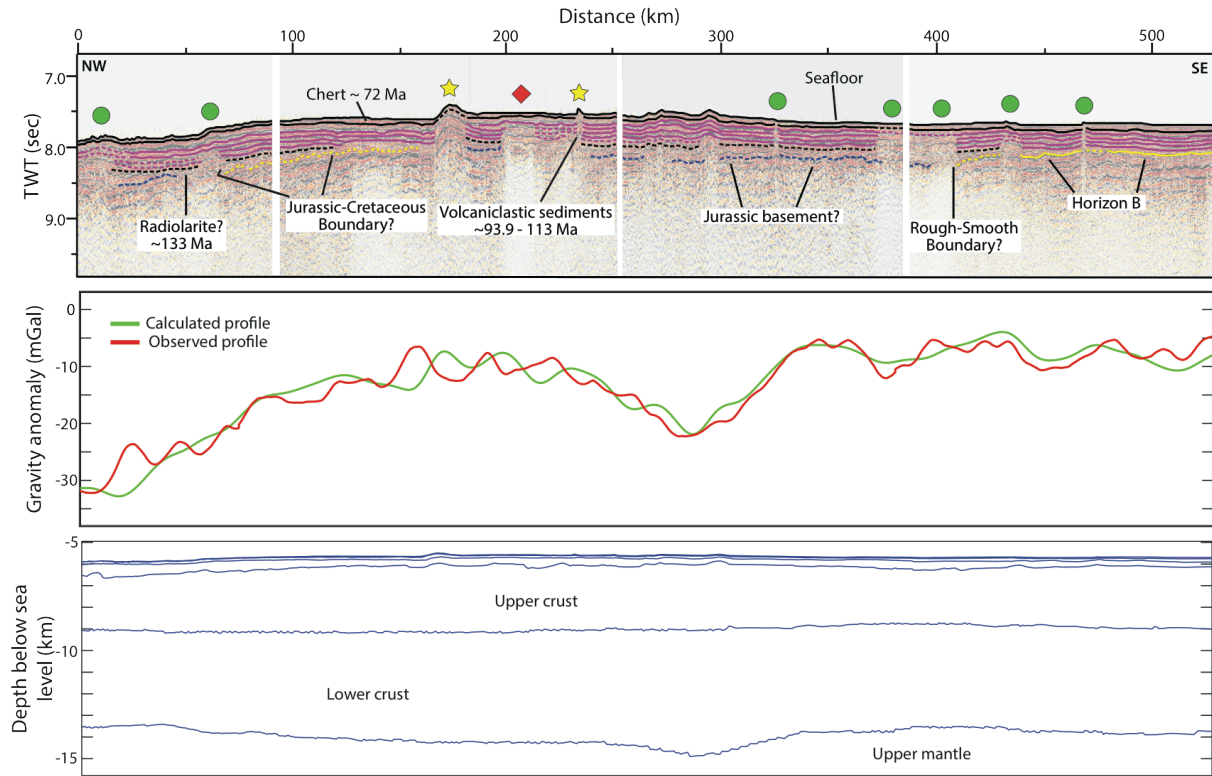


Figure 4c: FM35-12 Lines 10b1-10c. From top to bottom: First panel shows seismic interpretation of survey FM35-12 lines 10b1-10c with locations of volcanic features (yellow star – seamount, green circle – VSDZ, red diamond – sill). Next panel shows the observed versus modeled gravity profile and the bottom panel shows the crustal model used to calculate the modeled gravity profile.

4.2 Moho topography and crustal structure from gravity modeling

Forward gravity modeling results (Figure 4) show an average crustal thickness of $\sim 7.5 - 8$ km consistent with seismic velocity analysis by Kaneda *et al.* [2010]. Large seamounts are isostatically compensated by downward flexure of the Moho proportional to the seamount size while smaller volcanic features (VSDZs and sills) have little effect on Moho depth. Moho depth appears to be around 13.5 to 14 km below sea level, consistent with Kaneda *et al.* [2010] observations.

4.3 Magnetic anomaly modeling

Results from our magnetic model show that the volcanic features produce a minimal (up to a few nT), short wavelength effect on the overall magnetic anomaly that is not detectable when the whole crust is taken into account. Late stage sills and VSDZs have almost no effect on the longer wavelength anomalies produced by the crust (Figure 8).

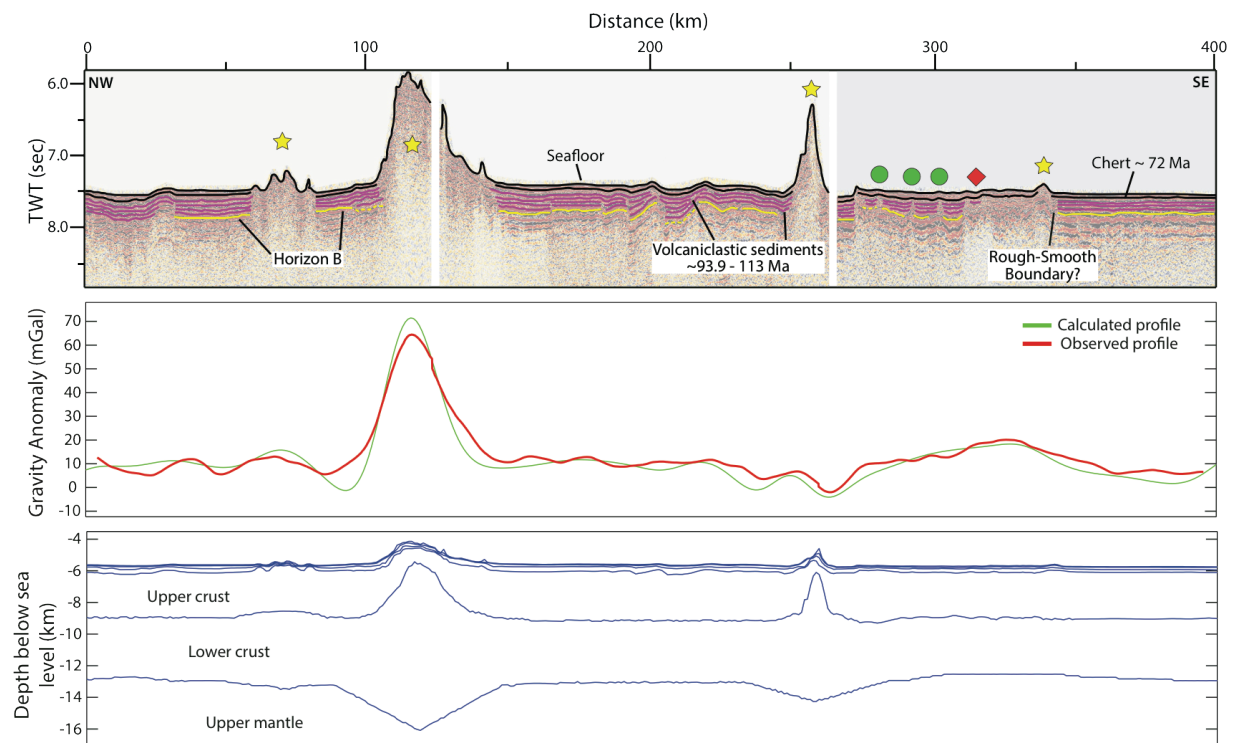


Figure 4d: FM35-12 Lines 12a2 - 12a4. From top to bottom: First panel shows seismic interpretation of survey FM35-12 lines 12a2c-12a4 with locations of volcanic features (yellow star – seamount, green circle – VSDZ, red diamond – sill). Next panel shows the observed versus modeled gravity profile and the bottom profile shows the crustal model used to calculate the modeled gravity profile.

5. Discussion

5.1 Mid Cretaceous late stage intra-plate volcanism

Early studies on the origin of intraplate volcanism in the western Pacific suggested that a superplume, an anomalously large volume magma source, existed under the region during the mid-Cretaceous [e.g. *Menard*, 1964; *McNutt and Fisher*, 1987; *Larson*, 1991; *McNutt*, 1998], and emplaced various seamount provinces such as the Marcus-Wake [*Van Waasbergen and Winterer*, 1993; *Winterer et al.*, 1993], Magellan [*Smith et al.*, 1989; *Koppers et al.*, 1998], and Mid Pacific Mountain seamount chains [e.g. *Schlanger et al.*, 1981; *Rea and Vallier*, 1983] (Figure 1 and 2). *Koppers et al.*, [2003a] conducted absolute $^{40}\text{Ar}/^{39}\text{Ar}$ age dating of igneous basement samples from these ‘superplume’ seamount provinces to more closely define the possible origin of volcanic emplacement, suggesting that these seamount provinces in the western Pacific were formed by magmatic activities induced by multiple, closely spaced, short-lived ‘plumelets’ that stemmed from a main magma body, and that magmatic upwelling was driven primarily by lithosphere weakening due to regional extension.

The evaluation of the age, size-frequency, and spatial distribution of volcanic features in the Pigafetta Basin provides a key to further understand the origin of intraplate volcanism in the western Pacific. Apparent ages of volcanic features in the Pigafetta Basin (Figure 6d) are consistent with surrounding seamount provinces and the Cretaceous volcanic event in the western Pacific [*Rea and Vallier*, 1983; *Smith et al.*, 1989; *Larson*, 1991; *Winterer et al.*, 1993; *Koppers et al.*, 2003a], indicating that the timing of volcanism in the Pigafetta Basin coincided with volcanism of the surrounding mid Cretaceous seamount provinces.

Global-scale analyses of seamount size frequency distributions using both satellite gravity [*Wessel*, 1997; *Wessel and Lyons*, 1997; *Wessel*, 2001; *Wessel et al.*, 2010; *Kim and Wessel*,

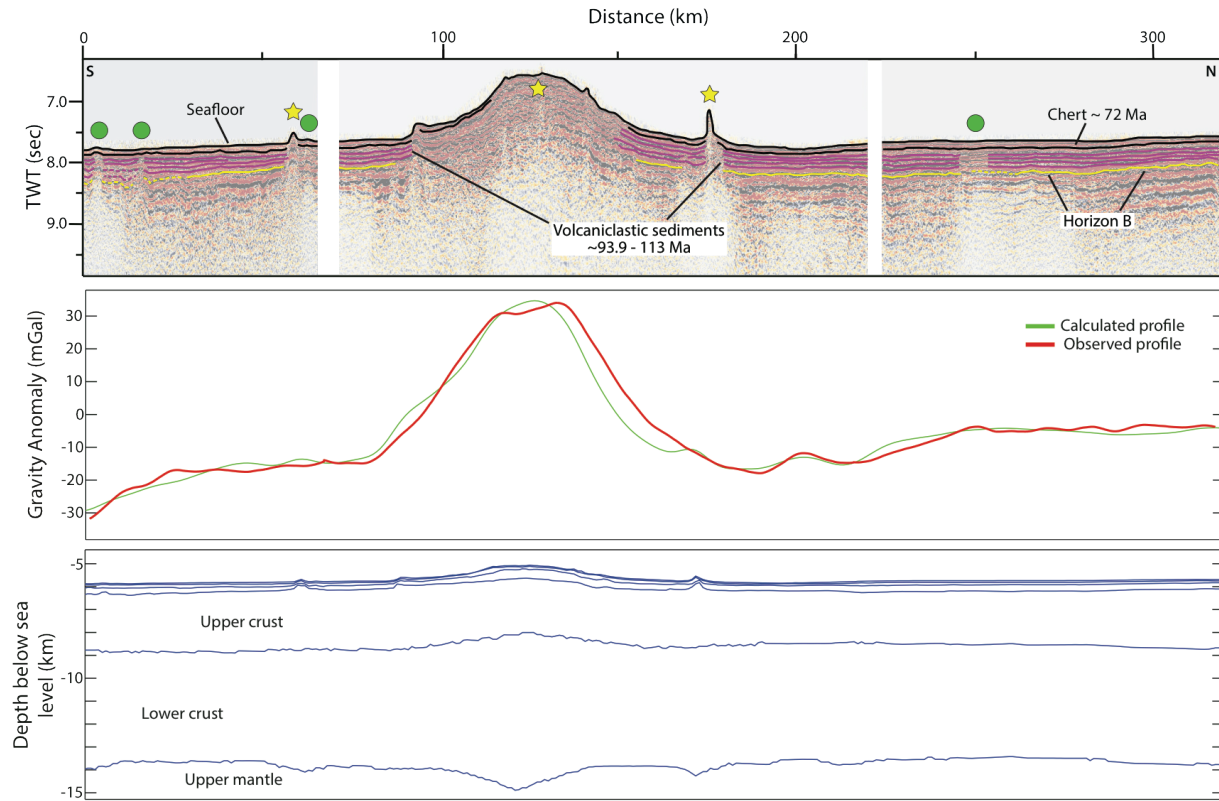


Figure 4e: FM35-12 Lines 9c - 9d2. From top to bottom: First panel shows seismic interpretation of survey FM35-12 lines 9c-9d2 with locations of volcanic features (yellow star – seamount, green circle – VSDZ, red diamond – sill). Next panel shows the observed versus modeled gravity profile and the bottom profile shows the crustal model used to calculate the modeled gravity profile.

2011] and shipboard bathymetry data [Jordan *et al.*, 1983; Smith and Jordan, 1987; Smith and Jordan, 1988; Hillier and Watts, 2007] have been conducted to reveal the nature of seafloor volcanism, magma generation, and to predict the global population of seamounts, including the seamount provinces in the western Pacific. The relationship between seamount populations and height distributions can be described either by an exponential [e.g. Jordan *et al.*, 1983; Smith and Jordan, 1987] or power law [e.g. Wessel, 2001; Wessel *et al.*, 2010] curve that provides a prediction of the global population for smaller seamounts, for which ship tracks are not available and the scale is beyond the resolution of satellite gravity data. The height distribution of volcanic features in the Pigafetta Basin follows the smaller spectrum (<1km) of the globally predicted seamount population curve (Figure 7), indicating that volcanism in the Pigafetta Basin represents

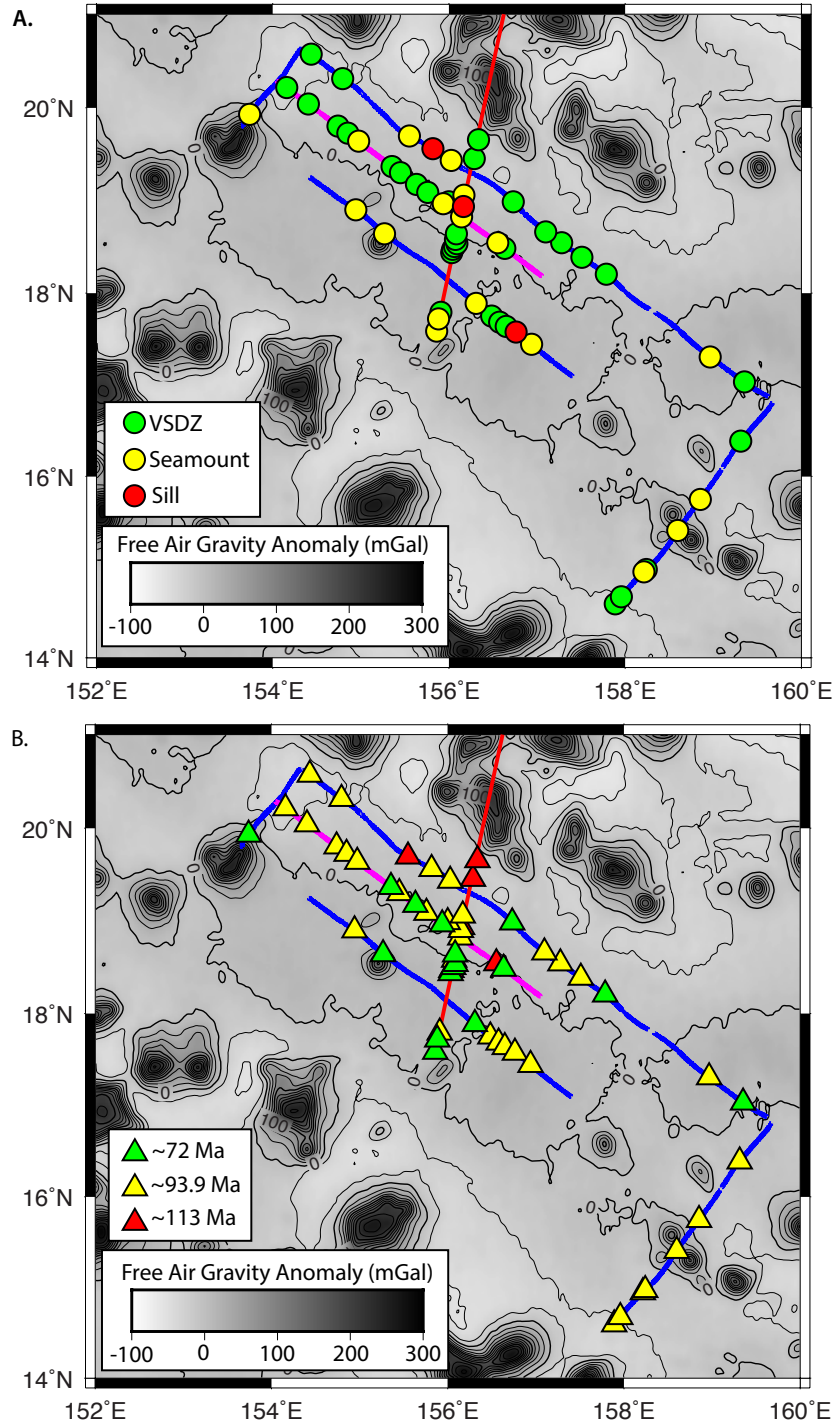


Figure 5: Map showing distribution of volcanic features across the Pigafetta Basin. **A.** Map showing spatial distribution of volcanic features over the seismic profile lines in the Pigafetta Basin. Map is overlain on top of a free air gravity map with 25 mGal contours to show the lack of basinwide correlation between gravity anomalies and location of volcanic features. **B.** Map showing apparent age distribution of volcanic features over the seismic profile lines in the Pigafetta Basin. Map is overlain on top of a free air gravity map with 25mGal contours. Gravity data from *Sandwell et al.* [2014] grid v.23.1.

the smallest end-member of global seamount populations. This non-uniqueness suggests that the source and emplacement mechanism of intraplate volcanism in the Pigafetta Basin should be analogous to the western Pacific seamount population.

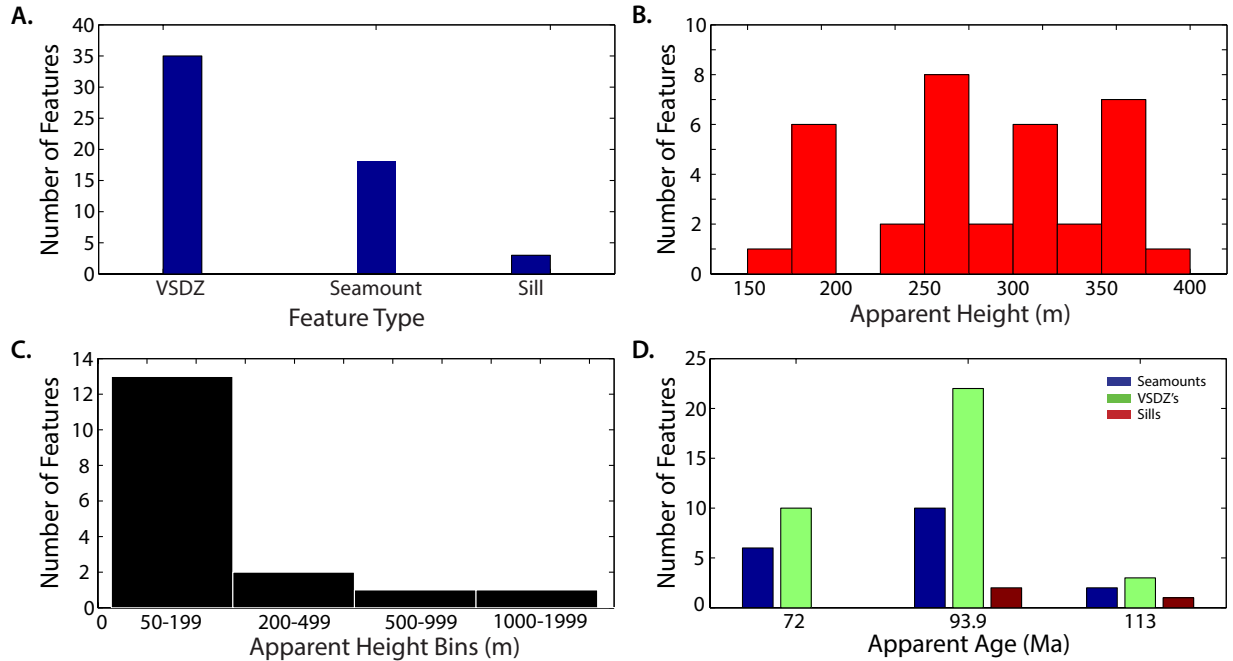


Figure 6: *Volcanic feature data.* **A.** Histogram showing number versus type of features documented by seismic profiles in the Pigafetta Basin. 35 VSDZ's, 17 Seamounts (excluding Grand Pacific), and 3 sills. Faults were noted as features crosscutting basement. **B.** Histogram showing height distribution of VSDZ's. Height measured from acoustic basement into sediment packet. **C.** Histogram showing height distribution of seamounts, height from seafloor. **D.** Histogram showing apparent ages of volcanic features determined by crosscutting relationships.

The spatial distributions of volcanic features in the Pigafetta Basin show no lineation or provincial assemblage; rather, their location of emplacement appears to be nonsystematic, making it consistent with the general distribution of seamounts in the western Pacific [e.g. *Koppers et al.*, 2003a]. Together with similarity in the age range and size distributions, we suggest that the volcanic features in the Pigafetta Basin can be attributed to intraplate volcanism that emplaced the surrounding seamount provinces.

One might argue that the intraplate volcanism in the Pigafetta Basin could be induced by mechanisms other than closely spaced “plumelets”, such as lithospheric cracking from

superplume uplift that associates with crustal deformation and thickening [e.g. *McNutt et al.*, 1990]. However, MTr5 shows no evidence of wholesale crustal deformation in the Pigafetta Basin [*Kaneda et al.*, 2010]. Furthermore, our gravity modeling results show a constant crustal thickness in the Pigafetta Basin, suggesting little crustal thickening by excess magmatism (Figure 4). Another possible scenario could be lithospheric cracking from differential plate cooling that is manifested by evenly spaced cracks in the lithosphere and linear volcanic ridges on the seafloor [e.g. *Winterer and Sandwell*, 1987; *Searle et al.*, 1995; *Lynch*, 1999; *Sandwell and Fialko*, 2004]. This mechanism is unlikely because the volcanic features do not appear along distinct ridges throughout the Pigafetta Basin, and we do not see evidence for regular spacing of lithosphere cracks in our seismic data.

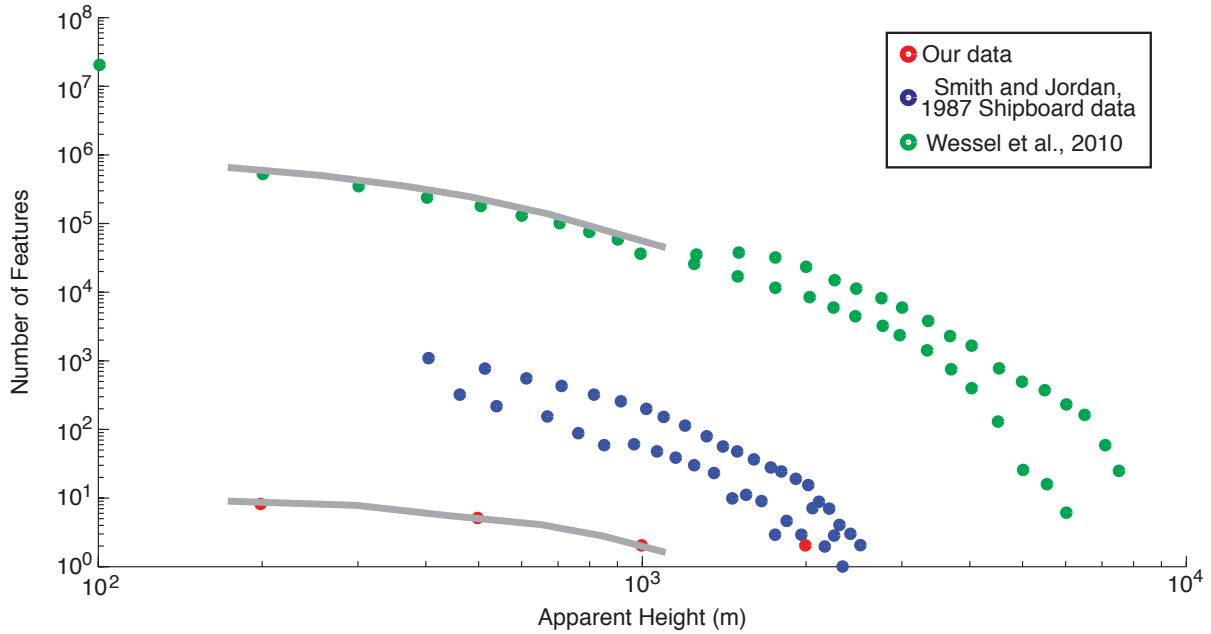


Figure 7: *Size-frequency comparison plot.* Log-log plot showing size frequency distribution of seamounts in the Pigafetta Basin (red dots) compared to global satellite (green) [*Wessel et al.* 2010] and Pacific-wide shipboard data (blue) [*Smith and Jordan* 1987]. Gray lines show correlation between seamounts < 1km height in Pigafetta Basin versus global population trend.

Recent numerical modeling results of mantle plume behavior shows that lateral offshoot/distribution of melt occurs in a variety of magmatic environments from on- and off-axis MOR regions to intraplate settings, often resulting in volcanic emplacement events at regions up to hundreds of km from the main conduit [e.g. *Olson, 1990; Ribe and Christensen, 1994; Sleep, 1996; Sleep, 2008; Katz and Weatherly, 2012*]. These results also augment the possible scenario that an anomalously large magma body existed under the western Pacific in the mid Cretaceous, feeding many smaller scale plumelets that spread laterally over the entire region and formed the seamount provinces and volcanic features we observe in this study [e.g. *Koppers et al., 2003a*].

5.2 Volcanic overprint or not? The survival of Jurassic basement

In their original study of Cretaceous volcanic sequences in the Pigafetta Basin, *Abrams et al. [1993]* pointed out a distinct change in reflection character of acoustic basement, transitioning from a flat lying “smooth” to a higher relief “rough” surface, named the Rough Smooth Boundary (RSB) (Figure 2). This topographic change in basement structure was interpreted to mark the extent of widespread middle Cretaceous sills covering Jurassic crust, and was mapped across the Pigafetta Basin according to its reflection characteristics [*Abrams et al., 1993*].

Our observation from MCS profiles over the Pigafetta Basin casts the interpretation of a distinct RSB by *Abrams et al. [1993]* into question. Although we see a change in acoustic basement reflection character throughout the Pigafetta Basin, the distribution of the transition from rough to smooth is ubiquitous, making it difficult to construct a straightforward interpretation on the unique RSB location for a few reasons. First, the RSB coincides with volcanic features on the seismic profiles (Figures 4c and d); therefore we prefer to conclude that the disruption of acoustic basement (and changing to “rough”) is probably a result of these

features instead of the edge of a widespread sill [Abrams *et al.*, 1993]. In addition, according to drilling results at Site 801, a Cretaceous sill would have intruded on top of >100 m of late Jurassic-early Cretaceous sediments in the Pigafetta Basin. At the RSB, the acoustic basement reflector appears to be continuous as it undergoes the topography change, indicating no existence of a >100 m sediment blanket. We suggest that the RSB is one of many topographic changes observed in the Pigafetta Basin, but does not uniquely define a sill-basement edge.

5.3 Possible implications of intra-plate volcanism as a source of magnetic overprint in the JQZ

The Jurassic Quiet Zone (JQZ) is Jurassic age oceanic crust where low amplitude, short wavelength magnetic anomalies are difficult to correlate [Heirtzler and Hayes, 1967; Hayes and Pittman, 1970; Vogt *et al.*, 1971; Larson and Chase, 1972; Hayes and Rabinowitz, 1975]. The JQZ has been most extensively studied in the Pigafetta Basin, where magnetic lineations have been mapped by various survey approaches [Hayes and Pittman, 1970; Larson and Chase, 1972; Larson and Pittman, 1972; Hilde *et al.*, 1976; Cande *et al.*, 1978; Handschumacher *et al.*, 1988; Sager *et al.*, 1998; Tivey *et al.*, 2006; Tominaga *et al.*, 2008]. Although it has been extensively investigated and anomaly correlations have pushed the Japanese lineations back to M44 the cause of the low amplitude anomalies remains unclear. One possible suggestion is that late stage magmatism could have overprinted the original magnetic signature of the ocean crust [Taylor *et al.*, 1968; Emery *et al.*, 1970; Vogt *et al.*, 1971; Barrett and Keen, 1976; Sager *et al.*, 1998; Tominaga *et al.*, 2008].

The results from our seismic interpretation and potential field models show, however, that there is no clear one to one correlation between (1) magnetic anomaly peaks and troughs versus

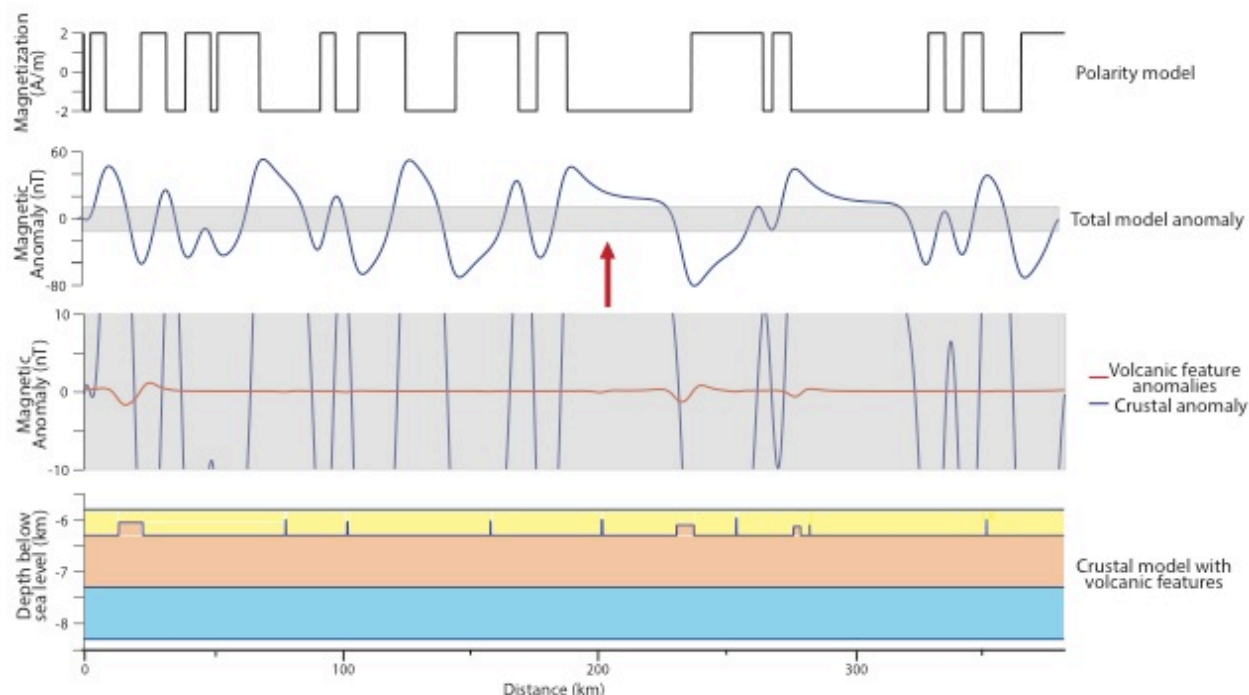


Figure 8: *Magnetic model.* From bottom to top, Bottom panel shows crustal model with locations of sills and VSDZs. Next model shows two magnetic anomalies, red is from volcanic features, blue is overall magnetic anomaly produced by the crust. Third panel is total magnetic field anomaly calculated from crustal model in panel 1, showing almost no effect from volcanic features (too small a value to affect overall signature). Top is the polarity block model used in crustal layer 2 (panel 1).

the location of sills and dikes, and (2) the decrease in magnetic anomaly amplitude (including the LAZ) versus the location of a gravity anomaly or lithosphere thinning or thickening (Figure 4b). Furthermore, our forward magnetic models show that VSDZs and sills have a minimal effect (up to a few nT) on magnetic anomalies (Figure 8); hence, we suggest that the Cretaceous volcanic features do not destroy the original magnetic signature of the ocean crust in the Pigafetta Basin, and that the Cretaceous volcanism is not a cause of the systematic decrease in anomaly amplitudes in the Jurassic Quiet Zone.

5.4 Implications for hydrothermal circulation from intra-plate volcanic features

Early lithosphere cooling models from heat flow experiments suggest that convective open system hydrothermal circulation remains active between ocean crust and seawater up to ~ 65 Ma after formation of the crust, after which the seafloor becomes sealed by increased sediment cover

with age and accumulation of precipitated minerals in pore spaces [Von Herzen and Uyeda, 1963; Anderson *et al.*, 1977; Stein and Stein, 1994]. At a local scale, on the other hand, seamounts and basement outcrops have been noted to concentrate heat and fluid flow and guide hydrothermal recharge and discharge at mid ocean ridge flanks [e.g. Fisher *et al.*, 2003; Hutnak *et al.*, 2008] and deep sea abyssal plains [e.g. Embley *et al.*, 1983; Noel and Hounslow, 1988] in crust up to 106 Ma [e.g. Noel and Hounslow, 1988]. Furthermore, recent models of hydrothermal circulation in oceanic basement coupled with heat flow measurements and seismic data indicate that convective hydrothermal circulation can continue in ocean crust up to tens of millions of years after the 65 Ma mark where basement topography is variable [e.g. Von Herzen, 2004; Fisher and von Herzen, 2005].

The volcanic features we observe in this study suggest a dynamic history of localized hydrothermal exchange from seafloor into deeper ocean crust in the Pigafetta Basin. The ages of widespread seamounts and subsurface intrusions in the Pigafetta Basin falls during the mid-Cretaceous (70-120 Ma), in ocean crust roughly 50 to 100 million years old. Carbonate precipitation in the crust can still be ongoing [Alt and Teagle, 1999], suggesting that at least closed system circulation is active in the Pigafetta Basin today. For facilitating possible open system hydrothermal circulation, ODP Hole 801C coring and wireline logging results showed that the upper basement is still highly permeable [Larson *et al.*, 1993]. The presence of seamounts and thinly sedimented intrusions observed as VSDZs in the Pigafetta Basin further indicate active open system hydrothermal circulation. Active open system hydrothermal circulation in ocean crust has also been recognized by (1) the presence of ‘pits’ in sediment above basement highs and faults [Moore *et al.*, 2007], and (2) varying sedimentation patterns affected by abyssal hills and multiple generations of faults in the sediment package [Tominaga *et*

al., 2011]. In this study we observe similar features to those noted by *Moore et al.*, [2007] above a few of the subsurface intrusions (ex. Line 10c, 10b1, and 12a4). We also note many faults in basement and sediments (Table 2), and sediment focusing between basement highs and lows, where basins have high sediment cover, and intrusions and seamounts have low sediment cover (Figure 4 all). The presence of these basement outcrops in the Pigafetta Basin indicates that on a local scale, the sediment packet does not seal the ocean crust, and that open system hydrothermal circulation could be active in ocean crust up to and possibly greater than 100 million years after its formation.

6. Conclusions

We derive the following conclusions in this study.

(1) The age, spatial, and size frequency distribution of volcanic features across the basin suggests that volcanism in the Pigafetta Basin coincided with that of the surrounding western Pacific mid-Cretaceous volcanic event and was emplaced in a similar style. Along with recent improvements to our understanding of plume behavior and lithosphere thickness, our results support the previously suggested scenario that multiple closely spaced, contemporaneous plumelets, fed by a deeper magmatic source, spread out under the western Pacific in the mid Cretaceous and emplaced the surrounding seamount provinces and smaller scale volcanic features we observe in the Pigafetta Basin [*Koppers et al.*, 2003a].

(2) The origin of the RSB in the Pigafetta Basin is in debate. We suggest that the RSB is more likely caused by volcanic disruption of the basement, a phenomena seen ubiquitously across the Pigafetta Basin, and that the RSB does not uniquely define a specific sill-basement edge.

(3) The subsurface volcanic structure in the Pigafetta Basin suggests that small-scale volcanic features disrupt basement on a local scale throughout the basin; however, forward magnetic modeling shows that the volcanic features are too small to disrupt the overall magnetic signature of the crust in the Pigafetta Basin. Therefore, there is no late stage magmatic overprint caused by intraplate volcanism in the Pigafetta Basin, suggesting that low-amplitude marine magnetic anomalies have a geomagnetic field origin in the Jurassic.

(4) The timing of volcanism suggests that on a local scale, open system hydrothermal circulation was reactivated in the Pigafetta Basin when the crust was 50 – 100 Ma old. Although we have no data to suggest that active hydrothermal circulation is ongoing, the presence of small

seamounts, subsurface intrusions, and rough basement topography in the Pigafetta basin suggests that open hydrothermal circulation could have existed in the Pigafetta Basin in crust well past 100 Ma.

APPENDIX

<u>Type</u>	<u>Longitude</u>	<u>Latitude</u>	<u>Apparent Age (Ma)</u>	<u>Apparent Height (m)</u>	<u>Line</u>
1	154.1583	20.2139	93.9	400	mp2-06
1	154.4025	20.0417	93.9	450	mp2-06
1	154.7386	19.8042	93.9	350	mp2-06
1	154.8517	19.7244	93.9	300	mp2-06
2	154.9736	19.6381	93.9	60	mp2-06
1	155.3556	19.3686	72	400	mp2-06
1	155.4503	19.3022	93.9	350	mp2-06
1	155.6339	19.1753	72	400	mp2-06
1	155.7583	19.0894	93.9	375	mp2-06
2	155.9369	18.9658	72	610	mp2-06
2	156.1428	18.8236	93.9	55	mp2-06
2	156.5514	18.5447	113	90	mp2-06
1	156.6347	18.485	72	350	mp2-06
1	157.8889	14.5956	93.9	350	9c
1	157.9583	14.6758	93.9	200	9c
2	158.2144	14.9494	93.9	120	9c
1	158.2417	14.9739	93.9	325	9c
2	158.5986	15.4053	93.9	700	9d1
2	158.8517	15.7458	93.9	410	9d1
1	159.3136	16.3869	93.9	200	9d2
1	159.3519	17.0308	72	250	10
2	158.9669	17.3061	93.9	215	10
1	157.7869	18.2056	72	300	10b1
1	157.5111	18.3889	93.9	250	10b1
1	157.2783	18.5431	93.9	275	10b1
1	157.0969	18.6614	93.9	275	10b2
1	156.7319	18.9858	72	400	10b2
2	155.5497	19.6958	113	80	10b3
2	156.0275	19.4356	93.9	100	10b3
3	155.8175	19.5619	93.9	NaN	10b3
1	154.7947	20.3136	93.9	200	10c
1	154.4342	20.5714	93.9	400	10c
2	153.7394	19.9297	72	5000	11
2	154.9431	18.9	93.9	285	12a2
2	155.2672	18.6422	72	1600	12a2
2	156.3078	17.8858	72	1050	12a3
1	156.4836	17.7506	93.9	275	12a4
1	156.5767	17.6844	93.9	275	12a4
1	156.6486	17.6358	93.9	275	12a4
3	156.7631	17.5742	93.9	NaN	12a4
2	156.9397	17.4408	93.9	145	12a4
2	155.859	17.5845	72	240	Mtr5
2	155.8814	17.7179	72	365	Mtr5
1	155.9095	17.7923	93.9	200	Mtr5
1	156.0333	18.4383	72	375	Mtr5
1	156.0418	18.472	113	150	Mtr5
1	156.0632	18.5046	72	400	Mtr5
1	156.0877	18.5374	72	325	Mtr5
1	156.0735	18.5824	93.9	350	Mtr5
1	156.0845	18.6404	72	400	Mtr5
1	156.1495	18.9047	93.9	200	Mtr5
3	156.162	18.9363	113	NaN	Mtr5
1	156..1709	18.9888	93.9	350	Mtr5
2	156.1701	19.06	93.9	80	Mtr5
1	156.2867	19.4552	113	200	Mtr5
1	156.3369	19.6561	113	300	Mtr5

Table 2: Volcanic feature data. 1 = VSDZ, 2 = Seamount, 3 = Sill

REFERENCES

REFERENCES

- Abrams, L. J., R. L. Larson, T. H. Shipley, and Y. Lancelot (1992), The Seismic Stratigraphy and Sedimentary History of the East Mariana and Pigafetta Basins of the Western Pacific, *Proc. Ocean Drill. Program, Sci. Results*, 129, 551–569.
- Abrams, L. J., R. L. Larson, T. H. Shipley, and Y. Lancelot (1993), Cretaceous Volcanic Sequences and Jurassic Oceanic Crust in the East Mariana and Pigafetta Basins of the Western Pacific, *AGU Geophys. Monogr. Ser.* 77, 77–101.
- Alt, J. C., and D. A. H. Teagle (1999), The Uptake of Carbon During Alteration of Ocean Crust, *Geochim. Cosmochim. Acta*, 63(10), 1527–1535.
- Anderson, R. N., M. G. Langseth, and J. G. Sclater (1977), The Mechanisms of Heat Transfer Through the Floor of the Indian Ocean, *J. Geophys. Res.*, 82(23), 3391–3409.
- Barrett, D. L., and C. E. Keen (1976), Mesozoic Magnetic Lineations, the Magnetic Quiet Zone, and Sea Floor Spreading in the Northwest Atlantic, *J. Geophys. Res.*, 81(26), 4875–4884.
- Bartolini, A., and R. L. Larson (2001), Pacific microplate and the Pangaea supercontinent in the Early to Middle Jurassic, *Geology*, 29, 375–378.
- Behl, R. J., and B. M. Smith (1992), Silicification of Deep-Sea Sediments and the Oxygen Isotope Composition of Diagenetic Siliceous Rocks from the Western Pacific, Pigafetta and East Mariana Basins, Leg 129, *Proc. Ocean Drill. Program, Sci. Results*, 129, 81–117.
- Cande, S. C., R. L. Larson, and J. L. LaBrecque (1978), Magnetic lineations in the Pacific Jurassic quiet zone, *Earth Planet. Sci. Lett.* 41(4), 434–440.
- Carbotte, S. M., and K. C. Macdonald (1994), Comparison of seafloor tectonic fabric at intermediate, fast, and super fast spreading ridges: Influence of spreading rate, plate motions, and ridge segmentation on fault patterns, *J. Geophys. Res.*, 99, 13609–13631.
- Castillo, P. R., P. A. Floyd, and C. France-Lanord (1992), Isotope Geochemistry of Leg 129 Basalts: Implications for the Origin of the Widespread Cretaceous Volcanic Event in the Pacific, *Proc. Ocean Drill. Program, Sci. Results*, 129, 405–413.
- Chadwick, W., and R. W. Embley (1998), Graben formation associated with recent dike intrusions and volcanic eruptions on the mid-ocean ridge, *J. Geophys. Res.*, 103(97), 9807–9825.
- Channell, J. E. T., E. Erba, M. Nakanishi, and K. Tamaki (1995), Late Jurassic-Early Cretaceous time scales and oceanic magnetic anomaly block models, in *Geochr., Timesc., and Strat. Corr.* edited by W. A. Berggren et al., pp. 51–63, *Soc. for Sediment. Geol.*, Tulsa, Okla.
- Clouard, V., and A. Bonneville (2001), How many Pacific hotspots are fed by deep-mantle plumes? *Geology*, 29, 695–698.

- Clouard, V., and A. Bonneville (2004), Ages of seamounts, islands and plateaus on the Pacific plate, In *Plates, plumes and paradigms*, Eds G. R. Foulger, J.H. Natland, D. Presnall, and D.L. Anderson, pp 71-90, *Geol. Soc. of Amer., Special Paper* 388, 2005.
- Coffin, M. F., L. A. Lawver, L. M. Galagan, and D. A. Campbell (2000), The Plates Project 2000 atlas of plate reconstructions (750 Ma to present day): Austin, University of Texas, Plates Project Progress Report 250, 89 p.
- Coffin, M. F., and O. Eldholm (1994), Large Igneous Provinces: Crustal Structure, Dimensions, and External Consequences, *Rev. Geophys.*, 32(1), 1–36.
- Contreras-Reyes, E., I. Grevemeyer, A. B. Watts, L. Planert, E. R. Flueh, and C. Peirce (2010), Crustal intrusion beneath the Louisville hotspot track, *Earth Planet. Sci. Lett.*, 289, 323–333.
- Curewitz, D., and J. A. Karson (1998), Geological Consequences of Dike Intrusion at Mid-Ocean Ridge Spreading Centers, *AGU Geophys. Monogr. Ser.* 106, 117–136.
- Embley, R. W., M. A. Hobart, N. Anderson, and D. Abbott (1983). Anomalous Heat Flow in the Northwest Atlantic: A Case for Continued Hydrothermal Circulation in 80-MY Crust. *J. Geophys. Res.*, 88, 1067–1074.
- Emery, K. O., E. Uchupi, J. D. Phillips, C. O. Bowin, E. T. Bunce, and S. T. Knott (1970), Continental Rise off Eastern North America, *Am. Assoc. Pet. Geol. Bull.*, 54(1), 44–108.
- Ewing, J., M. Ewing, T. Aitken, and W. J. Ludwig (1968), North Pacific Sediment Layers Measured by Seismic Profiling, *AGU Geophys. Monogr. Ser.* 12, 147-173.
- Fisher, A. T., E. E. Davis, M. Hutnak, V. Spiess, L. Zuhlsdorff, A. Cherkaoul, L. Christiansen, K. Edwards, R. Macdonald, H. Villinger, M. J. Mottl, C. G. Wheat, and K. Becker (2003), Hydrothermal recharge and discharge across 50 km guided by seamounts on a young ridge flank, *Nature*, 421, 618–621.
- Fisher, A. T., and R. P. Von Herzen (2005), Models of hydrothermal circulation within 106 Ma seafloor: Constraints on the vigor of fluid circulation and crustal properties, below the Madeira Abyssal Plain, *Geochemistry, Geophys. Geosystems*, 6, doi:10.1029/2005GC001013.
- Fisher, A. T., and C. G. Wheat (2010). Seamounts as Conduits for Massive Fluid, Heat, and Solute Fluxes on Ridge Flanks. *Oceanography*, 23(1), 74–87.
- Floyd, P. A., and P. R. Castillo (1992), Geochemistry and Petrogenesis of Jurassic Ocean Crust Basalts, Site 801, *Proc. Ocean Drill. Program, Sci. Results*, 129, 361-388.
- Fornari, J., M. Haymon, R. Perfit, T. K. P. Gregg, and H. Edwards (1998), Axial summit trough of the East Pacific Rise 9-10N: Geological characteristics and evolution of the axial zone of fast spreading mid-ocean ridges, *J. Geophys. Res.*, 103(98), 9827–9855.
- Gradstein, F. M., J. Hardenbol, and P. Van Veen (1994), A Mesozoic Time Scale, *J. Geophys. Res.*, 99, 51–74.

- Gradstein, F. M. (2012), *The Geologic Time Scale*, Elsevier Inc Publishing, London, UK.
- Hamilton, E. L. (1956), *Sunken Islands of the Mid-Pacific Mountains*, *Geol. Soc. Amer. Bull. Mem.* 64.
- Handschumacher, D. W., W. W. Sager, T. W. C. Hilde, and D. R. Bracey (1988), Pre-Cretaceous tectonic evolution of the Pacific plate and extension of the geomagnetic polarity reversal time scale with implications for the origin of the Jurassic Quiet Zone, *Tectonophysics*, 155, 365-380.
- Hansen, D. M., and J. Cartwright (2006), The three-dimensional geometry and growth of forced folds above saucer-shaped igneous sills, *J. Struct. Geol.*, 28(8), 1520–1535.
- Hayes, D. E., and W. C. Pittman (1970), Magnetic Lineations in the North Pacific: *Geol. Soc. Amer. Mem.* 126, 291-314.
- Hayes, D. E., and P. D. Rabinowitz (1975), Mesozoic Magnetic Lineations and the Magnetic Quiet Zone Off Northwest Africa, *Earth Planet. Sci. Lett.*, 28, 105–115.
- Heezen, B. C., A. G. Fisher, R. E. Boyce, D. Bukey, R. G. Douglas, R. E. Garrison, S. A. Kling, V. Krasheninnikov, A. P. Lisitzin, A. C. Pimm and the Shipboard Scientific Party (1969a), *Initial Reports Deep Sea Drill. Proj. Vol. VI, Leg 6, Site 46*, 57-66.
- Heezen, B. C., A. G. Fisher, R. E. Boyce, D. Bukey, R. G. Douglas, R. E. Garrison, S. A. Kling, V. Krasheninnikov, A. P. Lisitzin, A. C. Pimm and the Shipboard Scientific Party (1969b), *Initial Reports Deep Sea Drill. Proj. Vol. VI, Site 52*, 247-291.
- Heezen, B. C., I. D. MacGregor, H. P. Foreman, G. Forristall, H. Hekel, R. Hesse, R. H. Hoskins, E. J. W. Jones, A. Kaneps, V. A. Krasheninnikov, H. Okada, M. H. Ruef and the Shipboard Scientific Party (1971a), Lower Cretaceous Sediments beneath the Marcus Island Archipelagic Apron: DSDP Site 198, *Initial Reports Deep Sea Drill. Proj. Vol. 20*, 51-63.
- Heezen, B. C., I. D. MacGregor, H. P. Foreman, G. Forristall, H. Hekel, R. Hesse, R. H. Hoskins, E. J. W. Jones, A. Kaneps, V. A. Krasheninnikov, H. Okada, M. H. Ruef and the Shipboard Scientific Party (1971b), Mesozoic Chalks beneath the Caroline Abyssal Plain: DSDP Site 199, *Initial Reports Deep Sea Drill. Proj. Vol. 20*, 65-85.
- Heezen, B. C., J. L. Matthews, R. Catalano, J. Natland, A. Coogan, M. Tharp, and M. Rawson (1973), Western Pacific Guyots, *Initial Reports Deep Sea Drill. Proj. Vol. 20*, 653–723.
- Heirtzler, J. R., and D. E. Hayes (1967), Magnetic Boundaries in the North Atlantic Ocean, *Science*, 80, 157(3785), 185–187.
- Hess, H. H. (1962), History of the Ocean Basins, in *Petrologic Studies, Burl. Vol.* edited by A. E. J. Engel, H. L. James, and B. F. Leonard, pp. 599-620, Geol. Soc. Amer. Boulder, CO.
- Hilde, T. W. C., N. Isezaki, and J. M. Wageman (1976), Mesozoic Sea-Floor Spreading in the North Pacific, *AGU Geophys. Monogr. Ser.* 19, 205-226.
- Hillier, J. K., and A. B. Watts (2007), Global distribution of seamounts from ship-track bathymetry data, *Geophys. Res. Lett.*, 34(13), doi:10.1029/2007GL029874.

- Hutnak, M., A. T. Fisher, R. Harris, C. Stein, K. Wang, G. Spinelli, M. Schindler, H. Villinger, and E. Silver (2008), Large heat and fluid fluxes driven through mid-plate outcrops on ocean crust, *Nat. Geosci.*, *1*, 611–614.
- Jenkyns, H. C. (1980), Cretaceous anoxic events: from continents to oceans, *J. Geol. Soc. London.*, *137*, 171–188, doi:10.1144/gsjgs.137.2.0171.
- Jones, C. E., and H. C. Jenkyns (2001), Seawater Strontium Isotopes, Oceanic Anoxic Events, and Seafloor Hydrothermal Activity in the Jurassic and Cretaceous, *Am. J. Sci.*, *301*, 112–149.
- Jordan, T. H., Menard, H. W., & Smith, D. K. (1983). Density and Size Distribution of Seamounts in the Eastern Pacific Inferred from Wide-Beam Sounding Data. *J. Geophys. Res.*, *88*, 508–518.
- Kalnins, L. M., and A. B. Watts (2009), Spatial variations in effective elastic thickness in the Western Pacific Ocean and their implications for Mesozoic volcanism, *Earth Planet. Sci. Lett.*, *286*(1-2), 89–100.
- Kaneda, K., S. Kodaira, A. Nishizawa, T. Morishita, and N. Takahashi (2010), Structural evolution of preexisting oceanic crust through intraplate igneous activities in the Marcus-Wake seamount chain, *Geochemistry, Geophys. Geosystems*, *11*(10), doi:10.1029/2010GC003231.
- Karpoff, A. M. (1992), Cenozoic and Mesozoic Sediments from the Pigafetta Basin, Leg 129, Sites 800 and 801: Mineralogical and Geochemical trends of the Deposits Overlying the Oldest Oceanic Crust, *Proc. Ocean Drill. Program, Sci. Results vol. 129*, 3-30.
- Katz, R. F., and S. M. Weatherley (2012), Consequences of mantle heterogeneity for melt extraction at mid-ocean ridges, *Earth Planet. Sci. Lett.*, *335-336*, 226–237.
- Kent, D. V., and F. M. Gradstein (1985), A Cretaceous and Jurassic geochronology, *Geol. Soc. Am. Bull.*, *96*(11), 1419–1427.
- Kim, S., and P. Wessel (2011), New global seamount census from altimetry-derived gravity data, *Geophys. J. Int.*, *186*, 615–631.
- Koppers, A. A. P., H. Staudigel, J. R. Wijbrans, and M. S. Pringle (1998), The Magellan seamount trail: implications for Cretaceous hotspot volcanism and absolute Pacific plate motion, *Earth Planet. Sci. Lett.*, *163*(1-4), 53–68.
- Koppers, A. A. P., J. P. Morgan, J. W. Morgan, and H. Staudigel (2001), Testing the fixed hotspot hypothesis using $^{40}\text{Ar}/^{39}\text{Ar}$ age progressions along seamount trails, *Earth Planet. Sci. Lett.*, *185*, 237-252.
- Koppers, A. A. P., H. Staudigel, M. S. Pringle, and J. R. Wijbrans (2003a), Short-lived and discontinuous intraplate volcanism in the South Pacific: Hot spots or extensional volcanism?, *Geochemistry, Geophys. Geosystems*, *4*(10), doi:10.1029/2003GC000533.
- Koppers, A. A. P., H. Staudigel, and R. a. Duncan (2003b), High-resolution $^{40}\text{Ar}/^{39}\text{Ar}$ dating of the oldest oceanic basement basalts in the western Pacific basin, *Geochem. Geophys. Geosyst.*, *4*(11), doi:10.1029/2003GC000574.

- Korenaga, J. (2005), Why did not the Ontong Java Plateau form subaerially? *Earth Planet. Sci. Lett.*, 234(3-4), 385–399.
- Lancelot, Y., R. L. Larson, and A. Fisher (1990a), Ocean Drilling Program Leg 129 Preliminary Report: Old Pacific Crust, *Proc. Ocean Drill. Progr. Sci. Results, Leg 129*.
- Lancelot, Y., R. L. Larson, and Shipboard Scientific Party (1990b), *Proc. Ocean Drill. Program, Sci. Results*, Vol. 129. Ocean Drill. Program, College Station, Tex.
- Larson, R. L. (1991), Latest pulse of Earth: Evidence for a mid-Cretaceous superplume, *Geology*, 19, 547-550.
- Larson, R. L., and C. G. Chase (1972), Late Mesozoic Evolution of the Western Pacific Ocean, *Geol. Soc. Am. Bull.* 83 (12), 3627-3644.
- Larson, R. L., and W. C. Pitman (1972), World-Wide Correlation of Mesozoic Magnetic Anomalies, and its Implications, *Geol. Soc. Am. Bull.* 83 (12), 3645-3662.
- Larson, R. L., and T. W. C. Hilde (1975), A Revised Time Scale of Magnetic Reversals for the Early Cretaceous and Late Jurassic, *J. Geophys. Res.*, 80 (17), 2586-2594.
- Larson, R. L., and S. O. Schlanger (1981), Cretaceous volcanism and Jurassic magnetic anomalies in the Nauru Basin, western Pacific Ocean, *Geology*, 9, 480-484.
- Larson and W.W. Sager, R. L. (1992), Skewness of magnetic anomalies M0 to M29 in the northwestern Pacific, *Proc. Ocean Drill. Program, Sci. Results, 129*, 471–481.
- Larson, R. L., A. T. Fisher, R. D. Jarrard, and K. Becker (1993), Highly permeable and layered Jurassic oceanic crust in the western Pacific. *Earth Planet. Sci. Lett.*, 119(1-2), 71–83.
- Longhurst, Alan, R. (2007), Chapter 11: The Pacific Ocean, in *Ecological Geography of the Sea (Second Edition)*, Elsevier Inc. Academic Press, Oxford, UK.
- Lynch, M. A. (1999), Linear ridge groups: Evidence for tensional cracking in the Pacific Plate, *J. Geophys. Res.*, 104, 29321-29333.
- McNutt, M. K., and K. M. Fischer (1987), The South Pacific Superswell, *Geophys. Monogr. Ser. Seamounts, Islands, Atolls*, 43, 25–34.
- McNutt, M. K., E. L. Winterer, W. W. Sager, J. H. Natland, G. Ito, T. Japanese, and W. Guyots (1990), The Darwin Rise: A Cretaceous Superswell?, *Geophys. Res. Lett.*, 17(8), 1101–1104.
- McNutt, M. K. (1998), Superswells, *Rev. Geophys.*, 36(2), 211–244.
- Menard, H. W. (1964), *Marine Geology of the Pacific*, 271 pp., McGraw-Hill, New York.
- Moore, T. C., N. C. Mitchell, M. Lyle, J. Backman, and H. Pälike (2007), Hydrothermal pits in the biogenic sediments of the equatorial Pacific Ocean, *Geochem., Geophys. Geosyst.*, 8, doi:10.1029/2006GC001501.

- Morgan, J. P. (1971), Convection Plumes in the Lower Mantle, *Nature*, 230, 42–43.
- Morgan, W. J. (1972), Deep mantle convection plumes and plate motions, *Am. Assoc. Pet. Geol.*, 56(2), 203–213.
- Nagihara, S., C. R. B. Lister, and J. G. Sclater (1996), Reheating of old oceanic lithosphere: Deductions from observations, *Earth Planet. Sci. Lett.*, 139, 91–104.
- Nakanishi, M., K. Tamaki, and K. Kobayashi (1989), Mesozoic Magnetic Anomaly Lineations and Seafloor Spreading History of the Northwestern Pacific, *J. Geophys. Res.*, 94, 15437–15462.
- Nakanishi, M., K. Tamaki, and K. Kobayashi (1992), Magnetic anomaly lineations from Late Jurassic to Early Cretaceous in the west-central Pacific Ocean, *Geophys. J. Int.*, 109, 701–719.
- Nicholson, S. W., and S. B. Shirey (1990), Midcontinent Rift Volcanism in the Lake Superior Region: Sr, Nd, and Pb Isotopic Evidence for a Mantle Plume Origin, *J. Geophys. Res.*, 95, 10851–10868.
- Noel, M., and M. W. Hounslow (1988), Heat flow evidence for hydrothermal convection in Cretaceous crust of the Madeira Abyssal Plain. *Earth Planet. Sci. Lett.*, 90, 77–86.
- Ogg, J. G., S. M. Karl, and R. J. Behl (1992), Jurassic through Early Cretaceous Sedimentation History of the Central Equatorial Pacific and of Sites 800 and 801, *Proc. Ocean Drill. Program, Sci. Results*, 129, 571–613.
- Oikawa, M. and K. Kaneda (2007), Bouguer gravity anomaly in the western Pacific (in Japanese), *Tech. Bull. Hydrogr. Oceangr.*, 25, 96–99.
- Olson, P. (1990), Hot spots, swells and mantle plumes, *Magma Transp. Storage*, 33–51.
- Ozima, M., I. Kaneoka, K. Saito, M. Honda, M. Yanagisawa, and Y. Takigami (1983), Summary of Geochronological Studies of Submarine Rocks from the Western Pacific Ocean, in *Geodyn. West. Pacific-Indonesian Reg.*, ver. 11, edited by T.W.C. Hilde, and S. Uyeda, 137–142.
- Pariso, J. E., and H. P. Johnson (1991), Alteration Processes at Deep Sea Drilling Project/Ocean Drilling Program Hole 504B at the Costa Rica Rift: Implications for Magnetization of Oceanic Crust, *J. Geophys. Res.*, 96, 11,703–11,722.
- Parker, R. L. (1973), The Rapid Calculation of Potential Anomalies, *Geophys. J. Int.*, 31(4), 447–455.
- Plank, T. J. N. Ludden, C. Escutia, and Leg 185 Shipboard Scientific Party (2000), *Proceedings of the Ocean Drilling Program, Initial Reports*, vol. 185, Ocean Drill. Program, College Station, Tex.
- Planke, S., T. Rasmussen, S. S. Rey, and R. Myklebust (2005), Seismic characteristics and distribution of volcanic intrusions and hydrothermal vent complexes in the Vøring and Møre basins, in *Petroleum Geology: North-West Europe and Global Perspectives*, pp. 833–844.
- Pockalny, R. A., and R. L. Larson (2003), Implications for crustal accretion at fast spreading ridges from observations in Jurassic oceanic crust in the western Pacific, *Geochemistry, Geophys. Geosystems*, 4(1).

- Polteau, S., A. Mazzini, O. Galland, S. Planke, and A. Malthé-Sørenssen (2008), Saucer-shaped intrusions: Occurrences, emplacement and implications, *Earth Planet. Sci. Lett.*, 266(1-2), 195–204.
- Premoli Silva, I., J. Haggerty, F. Rack, and Shipboard Scientific Party (1993), *Proceedings of the Ocean Drilling Program, Initial Reports*, vol. 144, Ocean Drill. Program, College Station, Tex.
- Pringle, M. S. (1992), Radiometric Ages of Basaltic Basement Recovered at Sites 800, 801, and 802, Leg 129, Western Pacific Ocean, *Proc. Ocean Drill. Program, Sci. Results*, 129, 389–404.
- Purdy, G. M., L. S. L. Kong, G. L. Christeson, and S. C. Solomon (1992), Relationship between spreading rate and the seismic structure of mid ocean ridges, *Lett. to Nat.*, 356, 133–135.
- Rampino, M. R., & Stothers, R. B. (1988). Flood basalt volcanism during the past 250 million years, *Science*, 241(4866) 663-668.
- Rea, D. K., and T. L. Vallier (1983), Two Cretaceous volcanic episodes in the western Pacific Ocean, *Geol. Soc. Am. Bull.*, 94(12), 1430–1437.
- Ribe, N. M., and U. R. Christensen (1994), Three-dimensional modeling of plume-lithosphere interaction, *J. Geophys. Res.*, 99, 669–682.
- Ryan, W.B.F., S.M. Carbotte, J.O. Coplan, S. O'Hara, A. Melkonian, R. Arko, R.A. Weissel, V. Ferrini, A. Goodwillie, F. Nitsche, J. Bonczkowski, and R. Zemsky (2009), Global Multi-Resolution Topography synthesis, *Geochem. Geophys. Geosyst.*, 10, Q03014.
- Sager, W. W., C. J. Weiss, M. A. Tivey, and H. P. Johnson (1998), Geomagnetic polarity reversal model of deep-tow profiles from the Pacific Jurassic Quiet Zone, *J. Geophys. Res.*, 103(97), 5269–5286.
- Sandwell, D., and Y. Fialko (2004), Warping and cracking of the Pacific plate by thermal contraction, *J. Geophys. Res. B Solid Earth*, 109, doi:10.1029/2004JB003091.
- Sandwell, D. T., and W. H. F. Smith (2009), Global marine gravity from retracked Geosat and ERS-1 altimetry: Ridge segmentation versus spreading rate, *J. Geophys. Res.*, 114, doi:10.1029/2008JB006008.
- Sandwell, D. T., R. D. Muller, W. H. F. Smith, E. Garcia, and R. Francis (2014), New global marine gravity model from CryoSat-2 and Jason-1 reveals buried tectonic structure, *Science*, 80(6205), 65–67.
- Schlanger, S., H. C. Jenkyns, and I. Premoli-Silva (1981), Volcanism and Vertical Tectonics in the Pacific Basin related to Global Cretaceous transgressions, *Earth Planet. Sci. Lett.*, 52, 435–449.
- Schlanger, S., and R. Moherly (1986), Sedimentary and Volcanic History: East Mariana and Nauru Basin, *Initial Reports DSDP Leg 89*, 586, 653–678.
- Searle, R. C., J. Francheteau, and B. Cornaglia (1995), New observations on mid-plate volcanism and the tectonic history of the Pacific plate, Tahiti to Easter microplate, *Earth Planet. Sci. Lett.*, 131(October 1988), 395–421.

- Shipley, T., L. Gahagan, K. Johnson, and M. Davis (2012) Seismic Data Center, University of Texas Institute for Geophysics. URL <http://www.ig.utexas.edu/sdc/>.
- Showman, A. P., and T. E. Dowling (2014), *Encyclopedia of the Solar System (Third Edition)*, Elsevier Inc., Oxford, UK.
- Sleep, N. H. (1996), Lateral flow of hot plume material ponded at sublithospheric depths, *J. Geophys. Res.*, *101*, 28065–28063.
- Sleep, N. H. (2008), Channeling at the base of the lithosphere during the lateral flow of plume material beneath flow line hot spots, *Geochemistry, Geophys. Geosystems*, *9*, doi:10.1029/2008GC002090.
- Smith, W. H. F., H. Staudigel, A. B. Watts, and M. S. Pringle (1989), The Magellan Seamounts: Early Cretaceous Record of the South Pacific Isotopic and Thermal Anomaly, *J. Geophys. Res.*, vol. *94*, 10501-10523.
- Smith, D. K., and J. R. Cann (1990), Hundreds of small volcanoes on the median valley floor of the Mid Atlantic Ridge at 24-30 N, *Nature*, *348*, 152-156.
- Smith, D. K., and T. H. Jordan (1987), The Size Distribution of Pacific Seamounts. *Geophys. Res. Lett.*, *14*(11), 1119–1122.
- Smith, D. K., and T. H. Jordan (1988), Seamount Statistics in the Pacific Ocean. *J. Geophys. Res.* *93*(B4), 2899–2918.
- Stein, C. A., and S. Stein (1994), Constraints on Hydrothermal Heat-Flux Through the Oceanic Lithosphere From Global Heat-Flow, *J. Geophys. Res. Earth*, *99*, 3081–3095.
- Steiner, M. B. (2001), Tango in the Mid-Jurassic: 10,000-Yr geomagnetic field reversals, *Eos Trans. AGU*, *82*(47), Fall Meet. Suppl., Abstract GP12A-0205.
- Stothers, R. B. (1993), Flood Basalts and Extinction Events. *Geophys. Res. Lett.*, *20*(93), 1399–1402.
- Taylor, P. T., I. Zietz, and L. S. Dennis (1968), Geologic Implications of Aeromagnetic data for the Eastern Continental Margin of the United States, *Geophysics*, *33*(5), 755–780.
- Tivey, M. A., R. Larson, H. Schouten, and R. Pockalny (2005), Downhole magnetic measurements of ODP Hole 801C: Implications for Pacific oceanic crust and magnetic field behavior in the Middle Jurassic, *Geochem. Geophys. Geosyst.*, *6*(4), doi:10.1029/2004GC000754.
- Tivey, M. A., W. W. Sager, S.-M. Lee, and M. Tominaga (2006), Origin of the Pacific Jurassic quiet zone, *Geology*, *34*(9), 789-792.
- Tominaga, M., W. W. Sager, M. A. Tivey, and S.-M. Lee (2008), Deep-tow magnetic anomaly study of the Pacific Jurassic Quiet Zone and implications for the geomagnetic polarity reversal timescale and geomagnetic field behavior, *J. Geophys. Res.*, *113*(B7), doi: 10.1029/2007JB0005527.

- Tominaga, M., M. Lyle, and N. C. Mitchell (2011), Seismic interpretation of pelagic sedimentation regimes in the 18-53 Ma eastern equatorial Pacific: Basin-scale sedimentation and infilling of abyssal valleys, *Geochem., Geophys. Geosyst.*, *12*(3), doi:10.1029/2010GC003347.
- Van Waasbergen, R. J., and L. Winterer (1993), Summit Geomorphology of Western Pacific Guyots, *AGU Geophys. Monogr. Ser.* *77*, 335–366.
- Vine, F. J. (1966), Spreading of the Ocean Floor: New Evidence, *Science* (*80*), *154*(3755), 1405–1415.
- Vogt, P. R., C. N. Anderson, and D. R. Bracey (1971), Mesozoic magnetic anomalies, sea-floor spreading, and geomagnetic reversals in the southwestern North Atlantic, *J. Geophys. Res.*, *76*(20), 4796–4823.
- Von Herzen, R. P., and S. Uyeda (1963), Heat flow through the Eastern Pacific Ocean Floor, *J. Geophys. Res.*, *68*(14), 4219–4250.
- Von Herzen, R. P. (2004), Geothermal evidence for continuing hydrothermal circulation in older (>60 Ma) ocean crust, in *Hydrogeology of Oceanic Lithosphere*, edited by E. E. Davis and H. Elderfield, 414-450, Cambridge University Press, New York.
- Wessel, P. (1997), Sizes and Ages of Seamounts Using Remote Sensing: Implications for Intraplate Volcanism, *Science*, *277*(802), 802–805.
- Wessel, P., and S. Lyons (1997), Distribution of large Pacific seamounts from Geosat/ERS-1: Implications for the history of intraplate volcanism. *J. Geophys. Res.*, *102*, 459–475.
- Wessel, P. (2001), Global distribution of seamounts inferred from gridded Geosat/ERS-1 Altimetry. *J. Geophys. Res.*, *106*, 431–441.
- Wessel, P., D. T. Sandwell, and S. S. Kim (2010), The Global Seamount Census, *Oceanography*, *23*(1), 24-33.
- Wessel, P., W. H. F. Smith, R. Scharroo, J. Luis, and F. Wobbe (2013), Generic Mapping Tools: Improved Version Released, *EOS Trans. AGU*, *94*(45), p. 409-410.
- Wilson, J. T. (1963), A possible origin of the Hawaiian Islands, *Can J. Phys.*, *41*, 863-870
- Winterer, E. L., W. R. Riedel, R. M. Moherly, J. M. Resig, L. W. Kroenke, E. L. Gealy, G. R. Heath, P. Bronnimann, E. Martini, T. R. Worsley and the Shipboard Scientific Party (1969), *Initial Reports Deep Sea Drill. Proj. Vol. VII*, Site 61, 27–47.
- Winterer, E. L., J. L. Ewing, R. G. Douglas, R. D. Jarrard, Y. Lancelot, R. M. Moherly, T. C. Moore, P. H. Roth, S. O. Schlanger and the Shipboard Scientific Party (1971a), *Initial Reports Deep Sea Drill. Proj. Vol. 17*, Site 168, 235-246.
- Winterer, E. L., J. L. Ewing, R. G. Douglas, R. D. Jarrard, Y. Lancelot, R. M. Moherly, T. C. Moore, P. H. Roth, S. O. Schlanger and the Shipboard Scientific Party (1971b), *Initial Reports Deep Sea Drill. Proj. Vol. 17*, Site 170, 263-281.

Winterer, E. L., and D. T. Sandwell (1987), Evidence from en-echelon cross-grain ridges for tensional cracks in the Pacific plate, *Nature*, 329(6139), 534–537.

Winterer, E. L., J. H. Natland, R. J. V. A. N. Waasbergen, and R. A. Duncan (1993), Cretaceous Guyots in the Northwest Pacific: an Overview of Their Geology and Geophysics, AGU *Geophys. Monogr. Ser.* 77, 307-334.

Woods, M. T., and G. F. Davies (1982), Late Cretaceous genesis of the Kula plate, *Earth Planet. Sci. Lett.*, 58(2), 161–166.