Geological Background

Chapter

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Yasuto Itoh

Abstract

A tectonic graben within the central Kyushu Island, named the Hohi Volcanic Zone (HVZ), is buried by Plio-Pleistocene volcaniclastic materials. It is accompanied by affluent indicators of tensile stress and is often related to the N-S breakup of the continental crust of Kyushu. Such a hypothesis is, however, discordant with recent horizontal movements detected by global navigation satellite system (GNSS)-based analysis. The latest remote sensing data rather accord with the deformation field being provoked by westward indentation of the forearc sliver of southwest Japan according to intermittent dextral slips along the Median Tectonic Line (MTL). Although the MTL has a long-standing and complicated history of movements since the Cretaceous, it has been activated as a reverse, and then, right-lateral fault system under control of the convergence modes of the Philippine Sea Plate. The active MTL trace coincides with southern margin of the HVZ, and the right-stepping configuration of the dextral fault system resulted in the growth of a pull-apart basin around Beppu Bay.

Keywords: Kyushu, Hohi Volcanic Zone, Median Tectonic Line, Beppu Bay, Philippine Sea Plate, extrusion tectonics, pull-apart basin

1. Introduction

Located at an arc-arc junction, the island of Kyushu features a quite complicated evolutionary history accompanied with hyperactive volcanism and neotectonic movements. Among various controversies concerning the geology of this island, we selected two hot topics related to the book subject. They are, namely, the stress-strain state and fault architecture around central Kyushu.

2. Formation mechanism of the Hohi Volcanic Zone

The Hohi Volcanic Zone (HVZ) is a box-shaped tectonic graben buried by more than 5000 km^3 of volcaniclastic materials [1]. This volcanic province is studded with indications of prevailing tensile stress, such as dike swarms (see Figure 3 in Prologue), and often has been regarded as an eastern constituent of the active rift zone crossing central Kyushu. For example, Tada [2] advocated an N-S breakup of the continental crust based on 90-year-long repeated triangulation and trilateration surveys. However, the estimated extension rates significantly increase across the island from 1 mm/year in the HVZ (Pleistocene fault analysis [1]) to 14 mm/year around Shimabara Peninsula at the westernmost point of Kyushu (geodetic observation [2]). Such a lopsided motion seems to be contradictory to the working hypothesis of the rift valley as suggested by Itoh et al. [3].

An alternative mechanism of regional deformation in Kyushu was pointed out by Itoh and Takemura [4]. They took notice of lateral displacement of the forearc sliver of southwest Japan along the Median Tectonic Line (MTL). As shown in **Figure 1a**, the distribution of active strike-slip faults on the island basically follows a slip-line pattern provoked by long-standing westward crustal indentation. Recent horizontal fluctuation vectors for crustal movements detected by GNSS-based control points (**Figure 1b**) have agreed well with the hypothetical deformation field. Therefore, the strain in Kyushu is growing under the theory of extrusion just the same as structural buildup at a continental collision front.

As presented in **Figure 2a**, Itoh et al. [3] suggested that the HVZ has developed through two tectonic phases of the initial N-S extension (a-1) and succeeding pull-apart basin formation (a-2). Itoh and Inaba [5] suggested that a regime of increasing simple shear during the younger phase forced a northerly shift of the active MTL trace, which inevitably induced active migration of the depocenter. Reflecting this complex structural development, confined strong tension and compression are observed around the northwestern corner (rift-type monogenetic volcanism of Mt. Oninomi) and southeastern corner (subsurface inversion) of the basin, respectively (see **Figure 2a-2**). Spatiotemporal growth of the pull-apart sag is discussed in Chapter 4 based on a detailed seismic interpretation.

3. Fault architecture around Beppu Bay

The MTL has an exceptionally prolonged history of activity dating back to the Cretaceous, when a convergent margin along the northwestern Pacific suffered intense shear to form a regional detachment fault due to oblique subduction of oceanic plates [6]. It divides the southwestern Japan arc into the Inner and Outer Zones, which consist of the Paleozoic/Mesozoic accretionary complex intruded by voluminous igneous rocks and accreted/amalgamated bodies with high-pressure metamorphic rocks, respectively. In Kyushu, the Usuki-Yatsushiro Tectonic Line (**Figure 2b**) is a candidate for such a bisecting fault [7]. Its architectural context, however, remains controversial because later strong deformation brought about lateral transport of thrusted metamorphic terranes over the tectonic line [8–10].

After a dormant period in the Paleogene, the MTL was reactivated as a reverse, and then, right-lateral fault system under control of the fluctuant convergence of the Philippine Sea Plate [11, 12]. The dextral active fault along the southern coast of Beppu Bay is named the Saganoseki Fault (**Figure 2b** [13]). It is nearly continuous with the eastern part of the Oita-Kumamoto Tectonic Line, which coincides with the southern margin of the HVZ (see **Figure 2a-1**). On the opposite side of the volcano-tectonic graben, a swarm of superficial extensional features (Northern Marginal Fault Zone; **Figure 2b**) were confirmed by Shimazaki et al. [14]. Itoh et al. [3] interpreted the right-stepping configuration of the dextral MTL and the Beppu-kita Fault (**Figure 2b**) as confirming the emergence of a pull-apart basin bordered by large rollover structures on the Asamigawa and Central Beppu Bay Faults (**Figure 2b**).

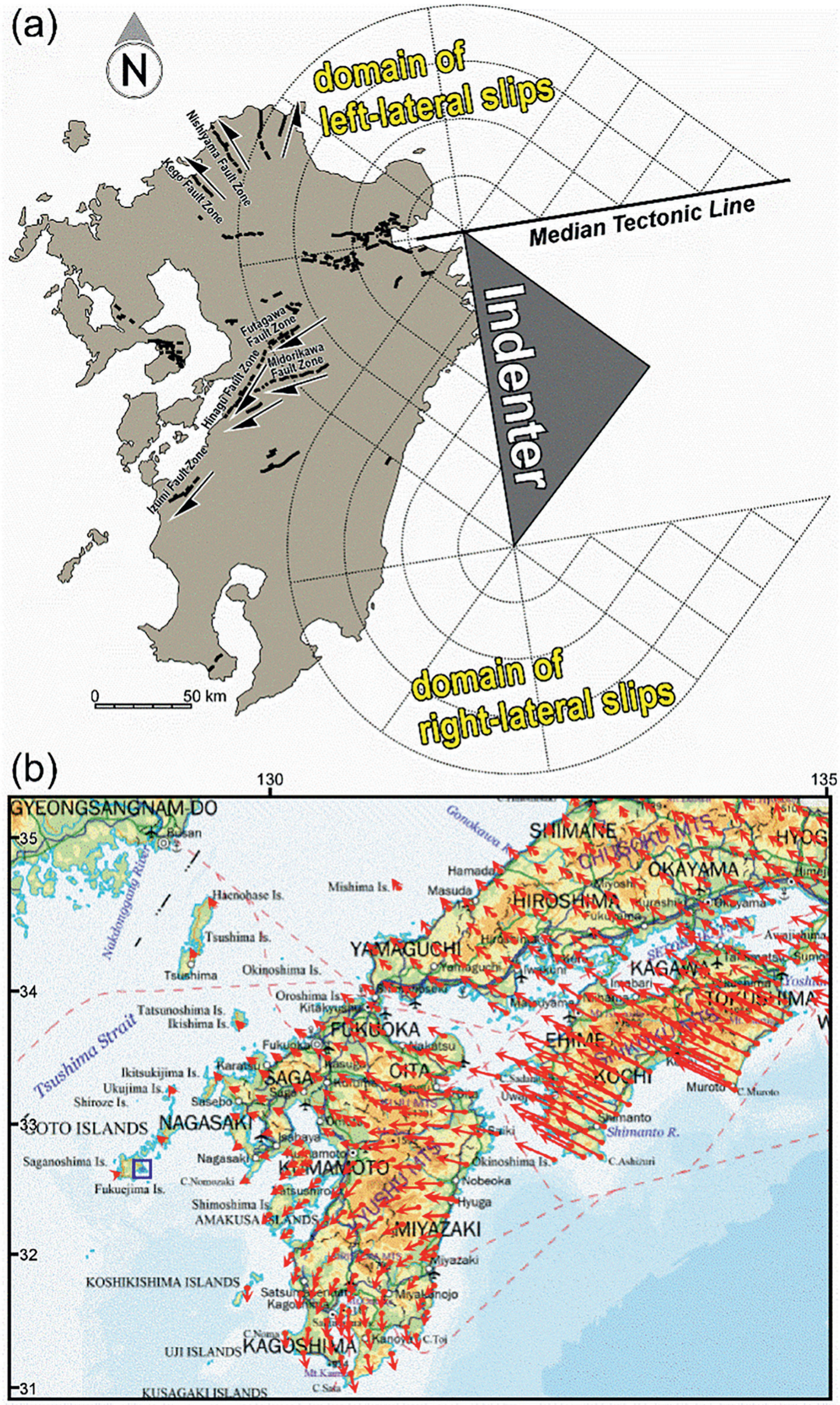

Figure 1.
(a) Crustal extrusion model of Kyushu after Itoh and Takemura [4]. (b) Recent horizontal fluctuation vectors (red arrows) of crustal movement detected by a GNSS-based control point (December 2017 to December 2022), as obtained from the website of the Geospatial Information Authority of Japan (https://mekira.gsi.go.jp/index.en.html). The fixed station on Fukue Island is shown by a blue square.

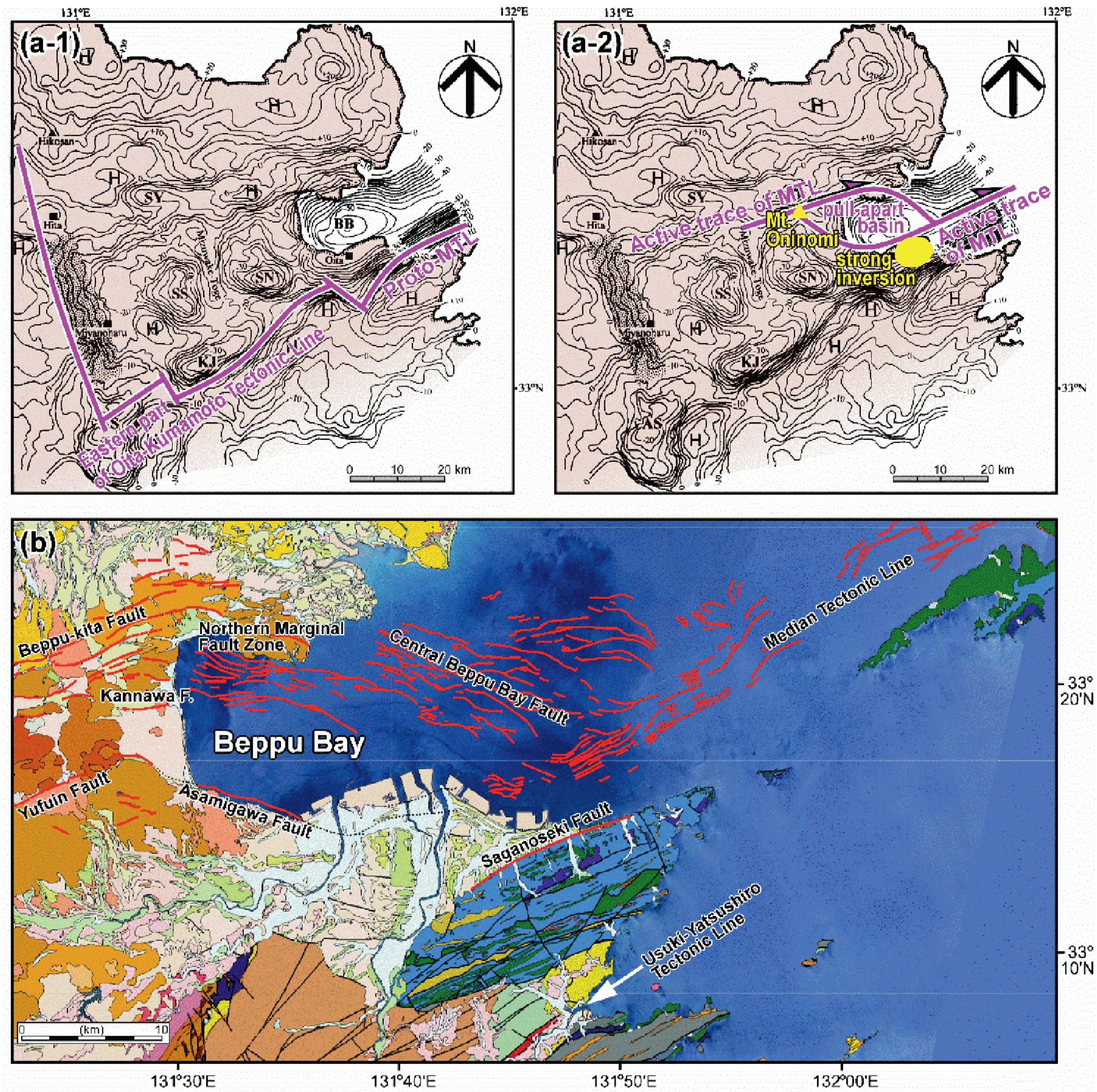

Figure 2.
(a) Development process of the HVZ since the Pliocene (1 = older, 2 = younger). The Bouguer gravity anomaly contours are after Itoh et al. [3]. Abbreviations for significant depressions are BB=Beppu Bay, SN=Shonai, KJ = Kuju, SY=Shin-Yabakei, SS=Shishimuta, and AS = Aso. The shaded zone shows a gravity slope on the western margin of the HVZ. (b) Neotectonic structural features around the study area are based on GeomapNavi, the geological map display system of the Geological Survey of Japan, AIST (https://gbank.gsj.jp/geonavi/geonavi.php#11.33.28137,131.78390).

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