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ABSTRACT

We undertook a boat expedition to explore the geological framework of a very remote, lesser-known island, in the Chilean Patagonia: the Diego de Almagro Island (latitude S51°33′). This uninhabited, ca. 400 km^2 Island is one of the very rare exposures of the Mesozoic accretionary subduction complex along the Chilean margin. Unstable weather, strong winds, steep topography, and very dense vegetation make an on-land mission difficult. Careful preparation based on high-resolution satellite images is advised to optimize shore access and minimize risks of injury. Despite a relatively important degree of regional re-equilibration of metamorphic assemblages due to sluggish exhumation through the forearc crust, our results have shown that the island is composed of a nappe stack of ocean-floor derived slivers of meta-sedimentary units that exhibit very different pressure-temperature-time paths during burial by subduction under the Chilean margin and subsequent exhumation. These rocks are witness to a complex thermal evolution of the subduction zone between Jurassic and Cretaceous times from granulite facies to blueschist facies conditions as well as multiple episodes of accretion at ca. 35–40 km in depth for almost 100 Ma over the Mesozoic era.

1. Introduction

The Diego de Almagro (DAI) is the last Island of a labyrinth formed by fjords, channels and peninsulas exposed on the western Patagonian coast, ca. 160 km WSW of the famous Torres Del Paine resort (Fig. 1a). Only very few boat expeditions have reached this Island. The pioneering work by Cecioni (1955) led to the identification of metamorphic series on the DAI. A second mission in the late 1970s reported the presence of blueschists on the western side of the Island (Forsythe et al., 1981). Two other missions undertaken in the late 1990s and in 2007 continued the exploration of the eastern and southern sides of the DAI (Hervé et al., 1999; Olivares et al., 2003; Hyppolito, 2010) and enabled a better understanding of pressure-temperature-time trajectories (e.g. Hervé et al., 1999; Willner et al., 2004) as well as a reconnaissance of the zircon age patterns of several metamorphic units (Hervé and Fanning, 2003). Despite this wealth of sparse observations, a comprehensive tectonic model based on a large amount of samples and widespread geochronological data was missing. It was also important to compare metamorphic ages for the various lithotypes encountered on the Island (e.g. blueschists, greenschists, garnet amphibolites; Willner et al., 2004) in order to better constrain the timing of tectonic emplacement against the SW Gondwana subduction margin during the Mesozoic (Mpodozis and Ramos, 2008). Last, it was also important to study zircon detrital age populations as well as metamorphic zircon rims to constrain the source of the subducted material forming the Island and the timing of peak burial metamorphism (e.g. Hervé and Fanning, 2003).

2. Exploration of the southern shore of the Diego de Almagro Island

The mission started with a flight down to Punta Arenasin Chile and a 3-h bus connection to the city of Puerto Natales. One of the major challenges was to find an experienced crew willing to sail for two weeks in the fjords and beyond. The western Patagonian coastline, subject to very unstable weather conditions, is one of the rainiest places on Earth with locally up to 7000 mm rainfall per year. According to local people, the season considered the most prone for field work spans December to February. Outside this window, snow can be expected down to the seashore. Weather can change extremely fast in this region of the world from a clear blue sky to a hurricane storm with winds up to 160 km/h in less than 6 h. For this reason, we left the harbor with a 36 h delay after having experienced a severe tempest which slightly damaged the

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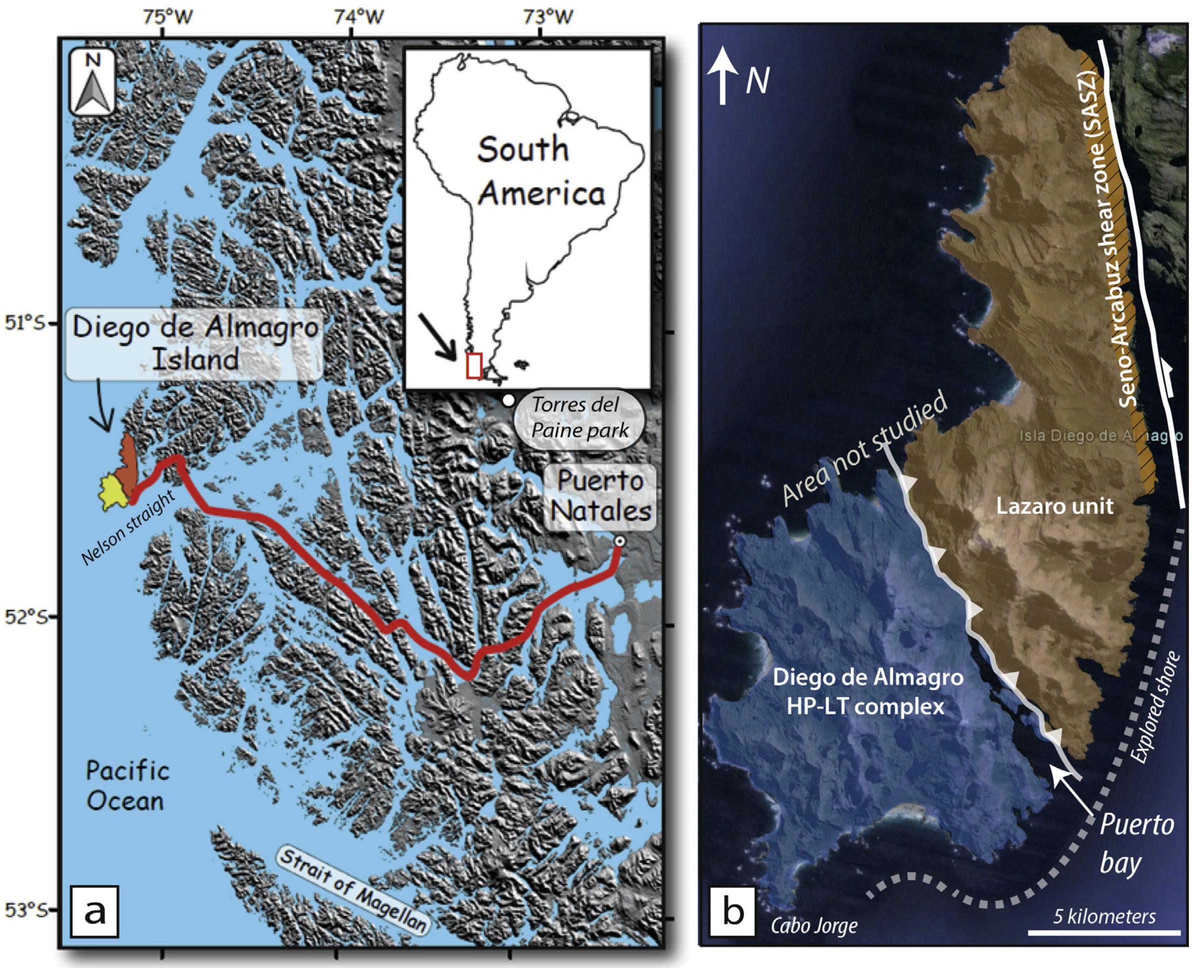

Figure 1. (a) Map localizing the Diego de Almagro Island in Patagonia. The red line indicates the path followed by the boat across the fjords. (b) Simplified geological structure of the Diego de Almagro Island (modified after Angiboust et al., 2018). HP-LT: high pressure, low-temperature.

outer boat hull due to several impacts with neighboring boats and crushing against the pier. It took half a day more to obtain the permit from the harbor authorities to pull anchor and leave towards the fjords. Two days later, we approached the shore of the uninhabited DAI after crossing the strong currents from the Nelson straight (Fig. 1a). Difficult weather conditions led us to seek a safe place to cast anchor inside the Puerto bay of the DAI (Fig. 1b). This locality constitutes an ideal base camp for exploring the southern shore of the Island as well as a safe shelter for the boat when weather conditions suddenly change (Fig. 2a). High wave amplitude makes zodiac access to the shore much more difficult towards the open Pacific Ocean on the SW end of the Island (Fig. 1b).

Coastline exposures and boulders, sometimes covered by lichens, algae and shells (Fig. 2b), expose decent outcrops. Jumping from the zodiac on these slippery boulders constitutes a perilous exercise which sometimes ends up in the 5 °C seawater. Waterproof field equipment is required and impermeable leather boots are highly recommended. Expect all the equipment, clothes and bags to be water-soaked from the first day until the end of the mission. The shore is surrounded by a nearly continuous stretch of jungle varying between 50 m and 300 m in width (Fig. 2c). Crossing this jungle to access inland exposuresis dangerous (very slippery) and exhausting. Behind the jungle, the topography rapidly steepens to reach 1044 m on the summit of the Island. The effort is rewarded by breathtaking panoramas and fairly continuous exposures due to recent glacier erosion (Fig. 2c). Progression still remains problematic due to a very dense cover of bushes. We advise for future expeditions to plan at least 30% of extra-time on the Island to compensate delays due to bad weather conditions and difficulties to access exposures.

3. Scientific progresses

Despite only six days of field work over a 15-days field campaign in February 2015, our mission permitted the reconnaissance of a stack of four tectonic sub-units on the Island: the blueschist unit and the garnet amphibolite unit (forming the Diego de Almagro HP-LT complex), the Lazaro unit and the Seno-Arcabuz shear zone (Figs. 1b and 2d). Each of them are separated by ductile shear zones where evidence for high pressure and retrograde deformation – recrystallization is visible. Geochemical investigations have shown that all the material forming the island derives from seafloor MORB material and deep sea sediments (Hyppolito et al., 2016; Angiboust et al., 2017). P-T-t data are reported in Angiboust et al. (2018) with metamorphic conditions spanning blueschist-, eclogite-, garnet amphibolite-, and high-pressure granulite-facies. All units (except the blueschist unit) underwent an amphibolitization stage at ca. 120 Ma near the base of the accretionary wedge. The late exhumation imprint (greenschist-facies) is pervasively distributed across the island and also localized along the main tectonic structures such as the base of the Lazaro unit (Willner et al., 2004; Hyppolito et al., 2016; Angiboust et al., 2017, 2018; Fig. 2d). The DAI nappe stack records more than 100 Ma of plate interface

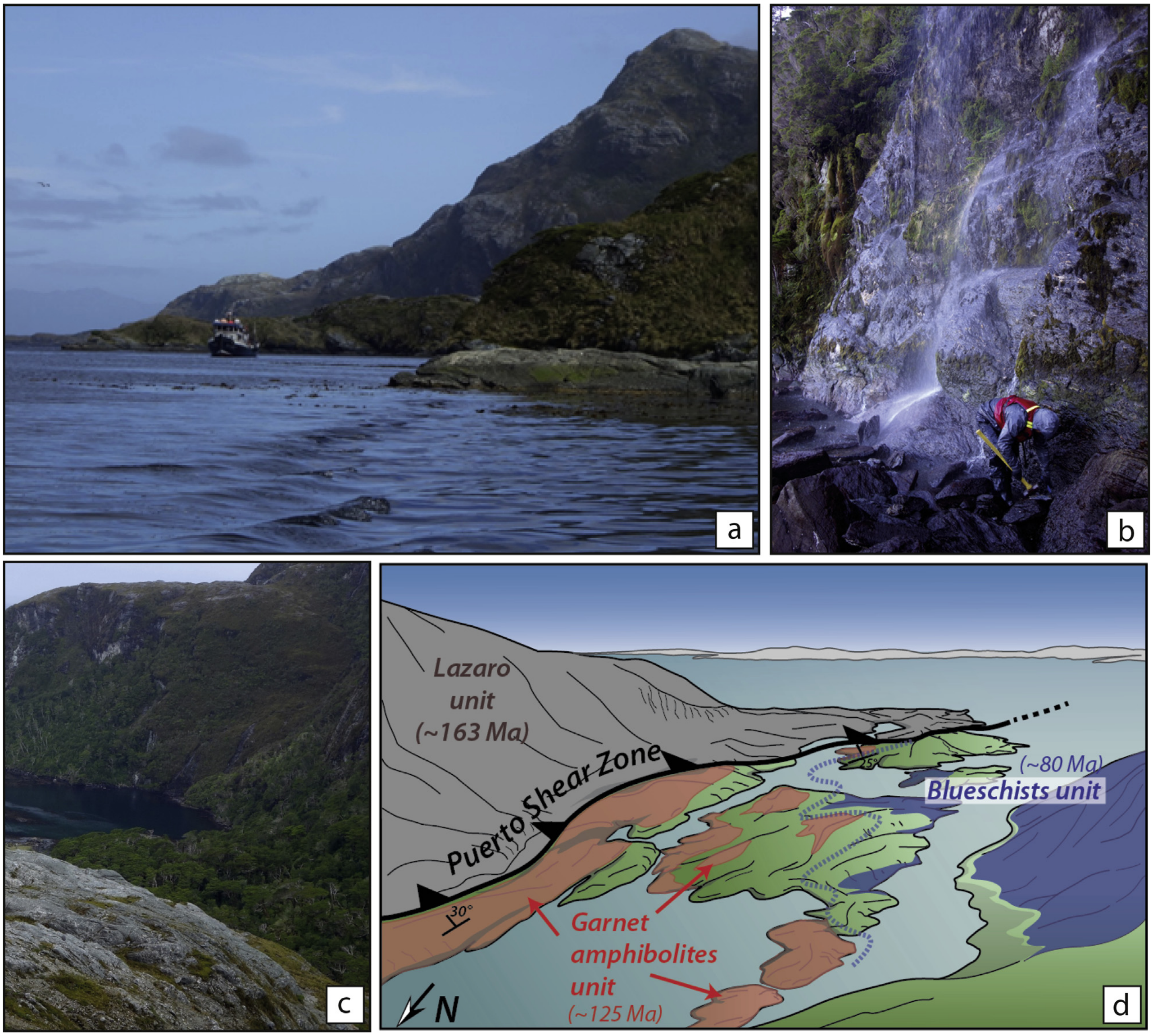

Figure 2. (a) Photograph showing one of the rare moments of quiescence of the sea near the entrance of the Puerto de Almagro bay. (b) Sampling of metasediments from the blueschist unit from the Diego de Almagro HP-LT complex (Fig. 1b) under a waterfall on the shore. Note the very steep and humid seashore conditions. (c) Picture taken over the coastal jungle showing a representative vision of the shoreline on DAI. (d) Sketch showing the morphology of the Puerto bay as well as tectonic units identified in the field. Green color is used when vegetation covers exposures. Full metamorphic age data is available in Hyppolito et al. (2016) and Angiboust et al. (2017, 2018).

deformation (between 170 Ma and 70 Ma; Angiboust et al., 2018) and therefore represents a key laboratory to understand dynamics and internal structure of a deep accretionary wedge (Fig. 2d; see also Willner, 2005). Our field investigations also revealed that most of the visited localities on DAI underwent strong retrogression in the greenschist-facies during slow exhumation across the fore-arc crust (e.g. Glodny et al., 2005). This process led to a pervasive overprint of most prograde features including potential paleo-fluid conduits and prograde brittle deformation markers.

4. Open questions and challenges for future expeditions

One of the most challenging targets remaining is the exploration of the northern shore of the DAI (Fig. 1b) to check the N–S lateral continuity of structures identified during our mission on the southern shore. Very high amplitude waves make the zodiac landing too risky. The scarcity of flat areas for landing and the very windy conditions make helicopter access a very hazardous option. A continuous cross-section across the Island is also lacking. Such expedition, which requires the help of field assistants to open a path across the bushes on the way, will certainly imply several nights of camping over the Island. Last, further field observations are necessary in the Seno Arcabuz Shear Zone region (Fig. 1b) to better map the contact with the Lazaro unit and also identify the fault network responsible for the late exhumation of the DAI against the buttress formed by the Madre de Dios paleo-accretionary complex and the South Patagonian batholith (Willner et al., 2004; Charrier et al., 2007).

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References

Angiboust, S., Hyppolito, T., Glodny, J., Cambeses, A., Garcia-Casco, A., Calderón, M., Juliani, C., 2017. Hot subduction in the middle Jurassic and partial melting of oceanic crust in Chilean Patagonia. Gondwana Research 42, 104–125.

Angiboust, S., Cambeses, A., Hyppolito, T., Glodny, J., Monié, P., et al., 2018. A 100 Ma-long window onto accretionary processes in the Patagonian Mesozoic subduction zone (Diego de Almagro Island, Chile). GSA Bulletin. https://doi.org/10.1130/B31891.1 (in press).

Cecioni, G., 1955. Noticias preliminares sobre la existencia del Paleozoico superior en el archipélago patagónico entre los 50 y los 52S, vol. 8. Publicación N8, Instituto de Geología, Universidad de Chile, pp. 181–202.

Charrier, R., Pinto, L., Rodríguez, M.P., 2007. Tectonostratigraphic evolution of the Andean Orogen in Chile. In: Moreno, T., Gibbons, W. (Eds.), The Geology of Chile. The Geological Society, pp. 21–114.

Forsythe, R., Dalziel, I.W., Mpodozis, C., Hall, B., Barrientos, S., 1981. Geologic studies in theouter Chilean fjords, R.V. Hero cruise 79-5. Antarctic Journal of the United States 15, 109–111.

Glodny, J., Lohrmann, J., Echtler, H., Gräfe, K., Seifert, W., Collao, S., Figueroa, O., 2005. Internal dynamics of a paleoaccretionary wedge: insights from combined isotope tectonochronology and sandbox modelling of the South-Central Chilean forearc. Earth and Planetary Science Letters 231 (1–2), 23–39.

Hervé, F., Prior, D., López, G., Ramos, V.A., Rapalini, A., Thomson, S., Lacassie, J.P., Fanning, M., 1999. Mesozoic blueschists from Diego de Almagro, Southern Chile. In: II South American Symposium on Isotope Geology, Actas, (Extended Abstract), pp. 318–321. Córdoba.

Hervé, F., Fanning, C.M., 2003. Early Cretaceous subduction of continental crust at the Diego de Almagro archipelago, Southern Chile. Episodes 26 (4), 285–289.

Hyppolito, T., Angiboust, S., Juliani, C., Glodny, J., Garcia-Casco, A., Calderón, M., Chopin, C., 2016. Eclogite-, amphibolite- and blueschist-facies rocks from Diego de Almagro Island (Patagonia): episodic accretion and thermal evolution of the Chilean subduction interface during the Cretaceous. Lithos 264, 422–440.

Hyppolito, T., 2010. Termobarometria, evolução tectono-metamórfica, e geoquímica de xistosazuis, rochaseclogíticas e litotiposassociados da ilha Diego de Almagro, Patagônia Chilena (Master thesis). São Paulo, Universidade de São Paulo, p. 173.

Mpodozis, C., Ramos, V.A., 2008. Tectónicajurásicaen Argentina y Chile: extensión, subducciónoblicua, rifting, deriva y colisiones. Revista de la Asociación Geológica Argentina 63 (4), 481–497.

Olivares, B., Cembrano, J., Hervé, F., López, G., Prior, D., 2003. Geometria y cinemática de La Zona de CizalleSenoArcabuz, Andes patagônicos, Chile. Revista Geológica de Chile 30, 39–52 (in Spanish with English abstract).

Willner, A.P., Hervé, F., Thomson, S.N., Massonne, H.J., 2004. Converging PT paths of Mesozoic HP-LT metamorphic units (Diego de Almagro Island, Southern Chile): evidence for juxtaposition during late shortening of an active continental margin. Mineralogy and Petrology 81 (1–2), 43–84.

Willner, A.P., 2005. Pressure–temperature evolution of a Late Palaeozoic paired metamorphic belt in North–Central Chile (34°–35°30′S). Journal of Petrology 46 (9), 1805–1833.

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