Available online at www.sciencedirect.com
ScienceDirect
Lithos 100 (2008) 1 – 13
LITHOS
www.elsevier.com/locate/lithos

Editorial

Links between ophiolites and Large Igneous Provinces (LIPs) in Earth history: Introduction

1. Introduction

Plate tectonics cycle, driven by lithospheric subduction and surface cooling, is responsible for the melting and primary differentiation of the Earth's mantle while also introducing chemical heterogeneity in the upper mantle. Oceanic crust generated at divergent plate boundaries commonly gets recycled into the mantle via subduction (Cloos, 1993), although the oceanic crust formed in subduction zone environments may become incorporated into continental margins through collisional and/or accretionary orogenic events as in ophiolites. The majority of the world's best preserved ophiolites appear to have formed in suprasubduction zone (SSZ) settings, where slab rollback, mantle flow in the arc wedge corner, subduction-induced mantle metasomatism, and upper plate extension collectively lead to oceanic crust formation (Pearce et al., 1984; Umino et al., 1990; Searle and Cox, 1999; Shervais, 2001; Ishikawa et al., 2002; Dilek and Flower, 2003; Beccaluva et al., 2005; Dilek et al., 2007). Systematic studies of SSZ ophiolites and suture zones in ancient and modern orogenic belts show that most of these ophiolites evolved in an older and wider ocean basin, following the initial collapse and consumption of its floor as a result of intra-oceanic subduction (Dilek and Flower, 2003; Harris, 2003; Garfunkel, 2006). Continued subduction, slab rollback, and upper plate extension and magmatism without any collisional interference would result in successive periods of forearc–protoarc splitting and hence in the formation of nested oceanic crust formation with larger age ranges; the modern and recent examples of this scenario include the Izu–Bonin–Mariana (IBM) system (Stern and Bloomer, 1992; Bloomer et al., 1995) and the northern Philippines (Encarnación, 2004; Yumul, 2007). The Jurassic ophiolites in California (Stern and Bloomer, 1992; Godfrey and Dilek, 2000), the Neo-Tethyan ophiolites in the Balkan Peninsula (Bortolotti et al., 2002; Saccani and Photiades, 2004; Beccaluva et al., 2005; Dilek et al., 2007) and in the Mediterranean region (Robertson, 2002; Dilek and Flower, 2003; Garfunkel, 2006) may be good ancient analogues for this model, although passive margin-trench collisions ultimately arrested these arc-trench rollback cycles and nested oceanic crust formation in the Neo-Tethyan domains and caused ophiolite emplacement in the early stages of collisional orogens.

Times of enhanced ophiolite genesis and emplacement in Earth history appear to coincide with the timing of major collisional events during the assembly of supercontinents (basin collapse and closure), dismantling of these supercontinents via continental rifting, and widespread development of Large Igneous Provinces (LIPs) (Coffin and Eldholm, 1994; Yale and Carpenter, 1998; Dalziel et al., 2000; Coffin and Eldholm, 2001; Ernst and Buchan 2002; Courtillot and Renne, 2003; Coffin and Eldholm, 2005; Ernst et al., 2005; Bryan and Ernst, in press) of oceanic affinity (oceanic plateaus, ocean basin flood basalts, and related seamount chains), suggesting spatial and temporal reactions between these events at global scales (Fig. 1; Dilek, 2003a). The most discrete ophiolite pulse during 180–140 Ma coincides with the formation and emplacement of the Tethyan, Caribbean, and some of the Circum-Pacific (Western Pacific and North American Cordillera) ophiolites. In the Tethyan system this timing marks the collapse of restricted basins between various Gondwana-derived subcontinents prior to the terminal closure of oceans and major continental collisions. In the Caribbean system this was the period when LIPs-generated oceanic lithosphere was accreted to the continental margins of northern South America and the northern Caribbean Islands (Lapierre et al., 1997; Kerr et al., 1998; Giunta et al., 2002).

The second important ophiolite pulse during the Late Cretaceous follows the Mid-Cretaceous "superplume

0024-4937/$ - see front matter
doi:10.1016/j.lithos.2007.08.001

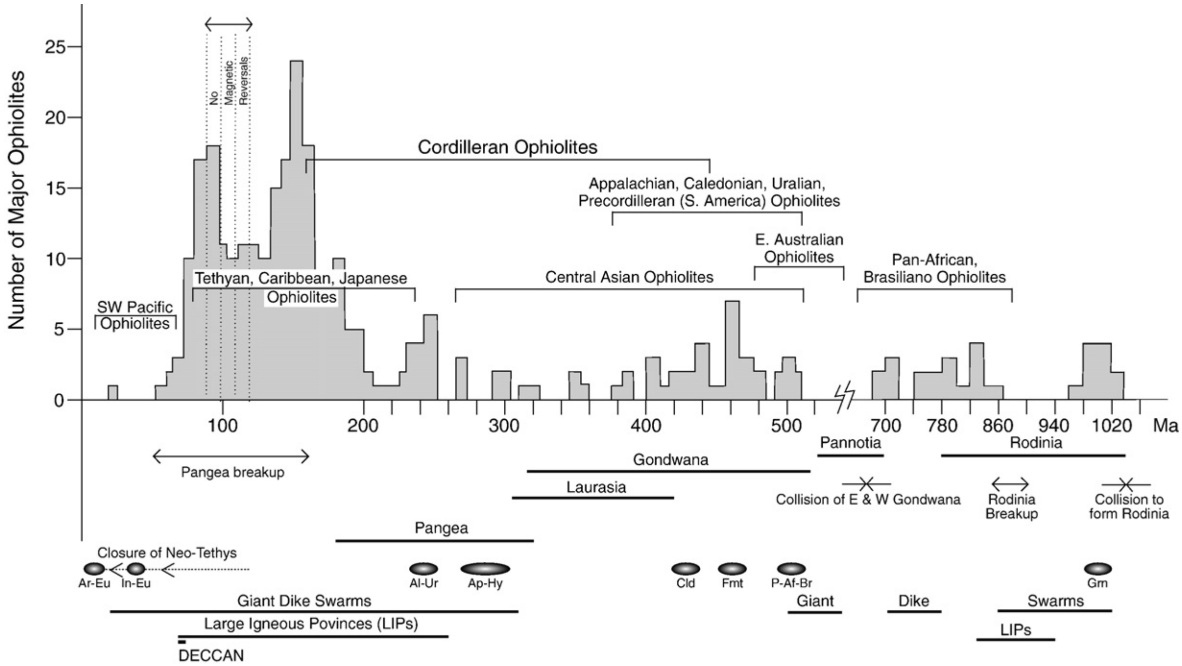

Fig. 1. Histogram showing the occurrence of major ophiolite pulses, the life spans of supercontinents and major collisional-orogenic events that led to their assembly, and formation of LIPs and giant dike swarms through time (only through the Neoproterozoic). Large Igneous Provinces include the 'classic' flood basalts, oceanic plateaus and also those LIPs in which the plumbing system of dike intrusions, sills, and layered intrusions are exposed (cf. Ernst and Buchan, 2001; Bryan and Ernst, in press). Note the change in time scale about the Phanerozoic–Proterozoic boundary. Abbreviations for orogenic events (from youngest to oldest): Ar–Eu, Arabia–Eurasia collision; In–Eu, India–Eurasia collision; Al–Ur, Altaid–Uralian orogenies of central Asia; Ap–Hy, Appalachian–Hercynian orogenies; Cld, Caledonian orogeny; Fmt, Famatinian orogeny; P–Af–Br, Pan–African–Brasiliano orogenies; Grn, Grenville and related orogenies. Period of 'No Magnetic Reversals' between 120 and 80 Ma concides with the mid-Cretaceous 'superplume' event (Larson, 1991). After Dilek, 2003a (see the extensive citation in this paper for the data source used in the compilation of this figure).

event" and coincides with the breakup of Pangea, the closure of Neo-Tethyan seaways, and the emplacement of giant dike swarms and LIPs (Fig. 1). Some of the Alpine–Apennine ophiolites that formed during the breakup of Pangea represent rift-related mafic–ultramafic assemblages (i.e., exhumed subcontinental mantle fragments) and/or remnants of embryonic ocean floor (Dilek, 2003b, and the references therein). The enhanced LIP formation (comprising mainly of flood basalts and giant dike swarms) and ophiolite generation in the Late Cretaceous seem to be linked in space and time through the increased seafloor spreading rates, extensive oceanic plateau formation and widespread compression at convergent margins (Larson, 1991; Vaughan, 1995; Dalziel et al., 2000; Dilek, 2003a; Vaughan and Scarrow, 2003). Spatial and temporal associations of rift volcanics showing within-plate alkaline basalt (WPB) to subalkaline tholeiitic basalt (akin to MORB) chemistry with passive margin sequences and ophiolites indicate that the plume activities and thermal anomalies in the mantle may have been responsible for the initial continental breakup, which led to the opening of ocean basins and seafloor spreading (i.e. Dilek and Rowland, 1993, and the references therein; Garzanti et al., 1999; Lapierre et al., 2004, 2006). The emplacement of contemporaneous continental flood basalts with similar geochemical signatures along some of the rifted continental margins supports this model (Garzanti et al., 1999; Song et al., 2001; Nikishin, 2002). This topic is further explored in the papers by Song et al., Xiao et al., and Mo et al., in this issue.

Correlation of the ophiolite pulses with major orogenic events that led to the assembly of supercontinents is particularly important during the Proterozoic and Paleozoic (Fig. 1), although our data from this time window of the Earth's history are rather limited. The collisional buildup of Rodinia around 1 Ga, the collision of East and West Gondwana and the construction of Pannotia (c. 700 and 600 Ma), Pan–African–Brasiliano orogenies (520–500 Ma), Caledonian–Famatian orogenies (460–440 Ma), Appalachian–Hercynian orogenies (c. 300–270 Ma), and Altaid–Uralian orogenies in central Asia (c 240 Ma) are the most important examples (Dilek, 2003a). Most ophiolites that formed during these orogenic events are the SSZ ophiolites