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Petrogenesis of Derraman Peralkaline granite (Oulad Dlim Massif, West African Craton Margin, Morocco): New constraints from zircon Hf and O isotopic compositions

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A B S T R A C T

The Archean Bulautad gneisses in the East of the Ouled Dlim domain adjacent to the Reguibat Rise (West African Craton, Southern Morocco) are intruded by peralkaline A-type granites. These granites form two kilometer-sized bodies, North Derraman and Derraman Highs, and a few small satellites. Prior studies have shown that the chemical and mineralogical compositions of these granites are remarkably uniform, and the North Derraman and Derraman Highs are hypersolvus aegirine–riebeckite granites. The North Derraman granite is intruding the *ca*. 3.12 Ga Bulautad gneisses while the Derraman High body is emplaced within the *ca*. 2.84 Ga Leglat schists. Here we present new zircon oxygen and hafnium isotopes data that help to understand the nature of the granite magmatic sources. We analyzed 20 Zircons from one sample in the North Derraman granite core. The zircons have an average $\delta^{18}O$ of 5.26 ± 0.22, similar to that of mantle zircons. Their εHf525Ma is negative between–3.8 and–11.1 with an average of–6.8 ± 0.7, and their Hf model age is *ca*. 1.8 Ga, similar to the available whole-rock Nd model age. Combined with previous whole-rock major and trace element studies, our new data suggest that the Derraman granite magmatic sources were *ca*. 1.8 Ga crustal fenites that formed by refertilization of lower crust granulites by mantle-derived alkaline melts and fluids, likely during the Paleoproterozoic alkaline magmatism that gave rise to the neighboring *ca*. 1.8 Ga Gleibat Lafhouda carbonatites. The so-generated fenites likely remained undisturbed in the crust until the Middle Cambrian, when they remelted during the rifting event that affected the northern Gondwana at that time.

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1. Introduction

The Derraman granites intrude the Bulautad gneisses of the Archean domain of the East of the Oulad Dlim Massif, thrust onto the Reguibat Rise of the West African Craton (Fig. 1; Bea et al., 2016). They have been dated from the Cambrian (525 ± 3 Ma; Bea et al., 2016) and interpreted as linked to the rifting of NW Gondwana. The Derraman granites are aegirine–riebeckite A-type granites (Loiselle and Wones, 1979), a volumetrically minor group of the granitoid rocks worldwide, which has attracted attention because of their peculiar geochemical characteristics (elevated HFSE, REE and F contents with high Fe/Mg and Ga/Al ratios) and of their specific geotectonic setting (non-orogenic setting, e.g., Bonin, 2007 and references therein; Eby, 1990, 1992). The nature of the magmatic sources and the relative contributions of the crust and mantle in the A-type granite petrogenesis remain a hotly debated subject at the present time (e.g., Bonin, 2007; Martin, 2006). A significant step to understand these issues has arisen from the combinations of U–Th–Pb, Lu–Hf and oxygen isotopic records in zircons contained in these granites (e.g., Hawkesworth and Kemp, 2006). The nearly identical ionic radii of Zr^{4+} and Hf^{4+} and the larger abundance of Zr make that Hf does not form minerals of its own, but is instead always incorporated in Zr minerals. As a consequence, zircon often contains between 0.5 and 1.5 wt.% Hf (Bea et al., 2006; Claiborne et al., 2006) and shows Lu/Hf of ≈ 0.06–0.08, the lowest ration among the minerals that contain Lu and Hf (Bea et al., 2017). Therefore, zircons preserve the original hafnium isotope composition of the magmatic source that formed the rocks they belong to. This allows using the $^{176}Hf/^{177}Hf$ ratio measured in zircon as an indicator of the contribution of crustal and mantle sources to granite genesis. However, the Hf isotopic system cannot constrain alone, generally, the contribution of mantle magmas in the granite sources. To elucidate this issue properly, Hf measurements must be combined with the oxygen isotope content (e.g., Hawkesworth and Kemp, 2006; Kemp et al., 2005, 2009), which is a robust discriminator of the mantle vs. crust contribution to the granite genesis (Valley et al., 2005).

Bea et al. (2016) have already studied the petrography, whole-rock major element, trace element, Sr and Nd isotope content, and determined the SHRIMP zircon U–Th–Pb age of the Derraman granites. The nature of the magmatic sources remains, however, problematic because of the discrepancy between the zircon U–Th–Pb crystallization age of 525 Ma, and the Nd model age of 1.8 Ga. Here, we report for the first time the zircon Hf-O isotopic compositions of the Derraman granites (20 zircons analyzed in one sample, Reg-122), to understand the discrepancy in the available ages. Based on the new data, we discuss the nature of the magma sources of the Derraman granites, the relative contribution of mantle and crust, and the relationship between the Cambrian A-type granite magmatism and the Paleoproterozoic carbonatitic magmatism in the framework of the West Reguibat Alkaline Province (WRAP, Bea et al., 2016; Montero et al., 2016).

2. Geological setting

The Derraman granites are intruding the Archean gneisses and metapelites of the easternmost part of the Oulad Dlim Massif (Fig. 1A). This massif is adjacent to the Archean TTG (tonalite–trondhjemite–granodiorite) rocks of the Reguibat Shield of the West African Craton (Bea et al., 2016; Montero et al., 2014).

The Oulad Dlim Massif is a crystalline domain formed of strongly and metamorphic deformed rocks (e.g., Michard et al., 2010). It is located west of the Archean Reguibat shield, and separated from it by a thin Paleozoic cover forming the Doloo Esder–Tiznagaten unit (also spelled Dhlou–Sdar–Tiznigated unit, Fig. 1B). This unit disappears to the south, putting the massif directly in contact with the Reguibat shield rocks (Fig. 1B). For Sougy (1962), the Oulad Dlim Massif is "the northern part of the Mauritanide belt" and therefore, a part of the Variscan orogen. Sougy and Bronner (1969) identified a number of nappes in this massif, as shown on the Geological Map of Morocco 1:1,000,000 (Hollard et al., 1985). On this map, the Mauritanide units are featured as a nappe synform preserved on top of the Reguibat shield. However, Villeneuve et al. (2006) discard this interpretation and, based on K–Ar radiometric data, they define four main west-dipping nappes, labeled from west to east: the Oued Togba; Sebkha Gezmayet, Dayat Lawda and Sebkha Matallah Units. Based on a large number of radiometric and isotopic data, Gärtner et al. (2013, 2015, 2016) adopt the same structural interpretation. In the frontal (eastern) part of the latter unit, Rjimati and Zemmouri (2002) individualized the Tiznigaten (sub-) unit made of green-schist-facies quartzite of supposedly Neoproterozoic age. Recent geochronological data, however, have shown that these quartzites are Cambrian–Ordovician (Villeneuve et al., 2015). Montero et al. (2017) found that the western part of the massif, corresponding to the eastern Oued Togba and the western Sebkha Gezmayet units, contains deformed Archean granites similar in age and geochemistry to those found in the Archean Reguibat shield. Accordingly, these authors consider the Oulad Dlim massif as a large synform affecting allochthonous units emplaced over the autochthonous Reguibat Shield, and recognize the following domains from east to west (Fig. 1B):

- the Archean domain of the East or Bulautad Unit (Montero et al., 2017), mainly formed of deformed leptinitic gneisses (the Bulautad gneisses) covered by the Leglat metapelites, dated to *ca.* 3.1 Ga and *ca.* 2.8 Ga, respectively (Bea et al., 2016; Montero et al., 2014). These rock materials host the Cambrian Derraman granites and the Paleoproterozoic Gleibat Lafhouda carbonatites;
- a Pan-African domain composed of two units: to the east, the Adrar–Sutuf metamafic complex consisting of *ca.* 605-Ma to *ca.* 585-Ma (Montero et al., 2017) gabbros, anorthosites and charnokites with scarce granitic gneisses, all of them strongly metamorphosed in the granulite or amphibole facies. To the west, a leucogranitic complex with SHRIMP zircon U–Th–Pb ages between *ca.* 590 to *ca.* 570 Ma (Montero et al., 2017);
- the Archean domain of the West mostly formed of the Gareg syeno-granites and monzogranites with SHRIMP zircon U–Th–Pb ages between 2.90 ± 0.1 and 2.95 ± 0.1 Ga (Montero et al., 2017);
- a narrow band of strongly deformed *ca.* 603-Ma to *ca.* 595-Ma Pan-African granites (Montero et al., 2017);

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