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160 Ma of sporadic basaltic activity on the Languedoc volcanic line (Southern France): A peculiar case of lithosphere–asthenosphere interplay

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ABSTRACT

The N–S Languedoc volcanic province between the French Massif Central and the Mediterranean Sea is characterized by sporadic, scattered, low volume (~2 km^3) and geochemically homogeneous alkali basaltic activity, spanning from 161 to 0.5 Ma. The existence of magmatic activity of such a long duration within such a small area (~140 km long and ~60 km wide), in spite of the extensive shift to the East of the European plate (about 2500 km during the last 160 Ma) is problematic. Trace-element abundances in lavas suggest low degrees of melting (1–5%) in the spinel–garnet transition zone of an enriched lherzolitic source. The lavas display rather large ranges in Sr isotopic ratios (0.70307–0.70436). The $^{143}Nd/^{144}Nd$ ratio variations are smaller (0.51268–0.51300) and these of $^{206}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ are 18.745–19.515, 38.532–39.228 and 15.567–15.680 respectively. The Languedoc lithospheric mantle, as sampled by xenoliths, is globally similar to the Pyrenees lithosphere. The xenoliths show also rather large Sr, Nd and Pb isotopic variations ($^{87}Sr/^{86}Sr$: 0.70287–0.70578; $^{143}Nd/^{144}Nd$: 0.51256–0.51414; $^{208}Pb/^{204}Pb$: 37.772–39.041; $^{206}Pb/^{204}Pb$: 17.901–19.353) except for $^{207}Pb/^{204}Pb$ (15.570–15.620). The $^{206}Pb/^{204}Pb$ and La/Sm ratios are positively correlated both in xenoliths and lavas. The increase of the $^{206}Pb/^{204}Pb$ (which could be interpreted as participation of the European Asthenospheric Reservoir, EAR) is probably related to volatile-rich (carbonated?) fluid percolation. This is corroborated by LILE and HFSE patterns observed in several xenoliths. Therefore, our data on lavas and xenoliths suggest a lithospheric origin for this long-lived magmatism. We propose (1) that the role of the asthenosphere in the Languedoc volcanism was restricted to volatile-rich fluid supplying and (2) that the fluid injection within the lithosphere may be related to the arrival of the Central Atlantic Plume head beneath Western Europe about 70 Ma ago. In this model, the isotopic signature of the oldest lavas (> 70 Ma) would be that of the mantle lithosphere, inherited from Hercynian processes. The signatures of the subsequent lavas would be driven by the metasomatic component stored within the lithosphere and preferentially mobilized during incipient melting. This metasomatised lower lithosphere was close to its solidus and small changes in P (or T) triggered incipient melting leading to basaltic volcanism. Successive local re-adjustments of the lithospheric blocks, which accompanied the Meso-Cenozoic evolution of the Thetys Ligurian margin towards the present Mediterranean margin, are the probable cause of these changes and so the sporadic volcanic activity in Languedoc is unrelated to deep asthenospheric processes.

1. Introduction

The origin of the Cenozoic alkali magmatism in Western Europe is still widely debated and widely varying models include: Miocene "hot spot(s)" (e.g. Granet et al., 1995) or "wet spot(s)" (cf. Wilson, 2007); superposition of active (Oligocene) and passive (Miocene) rifting (Michon and Merle, 2001) and Eocene impingement of the "Central Atlantic Plume" on the European continent related to the opening of the Atlantic Ocean (Piromallo et al., 2008). In most of these models the respective contributions of lithosphere and asthenosphere in the magma genesis are not clearly defined. Furthermore, the causes of melting, e.g. thermal anomaly (Sobolev et al., 1996) and/or injection of volatile-rich melts (e.g. Downes, 2001), remain elusive. Furthermore, the role of the Alpine orogenesis in determining the location of the volcanism and the magmatic development, are still questionable (Michon and Merle, 2001; Piromallo et al., 2008).

Despite the low volume of erupted lavas (~2 km^3 on the whole) and their relatively uniform basaltic compositions, the Languedoc volcanic district (Southern France, Fig. 1) is probably one of the best places in Europe to shed new light on several of these issues, because —(1) the episodic volcanic activity spans from the Mid-Jurassic to Quaternary—this long-term activity is seen nowhere else in Europe; (2) its exceptional geological location (Fig. 1): half-way between the Pyrenean and Alpine belts, on the Gulf of Lion rim and on the South

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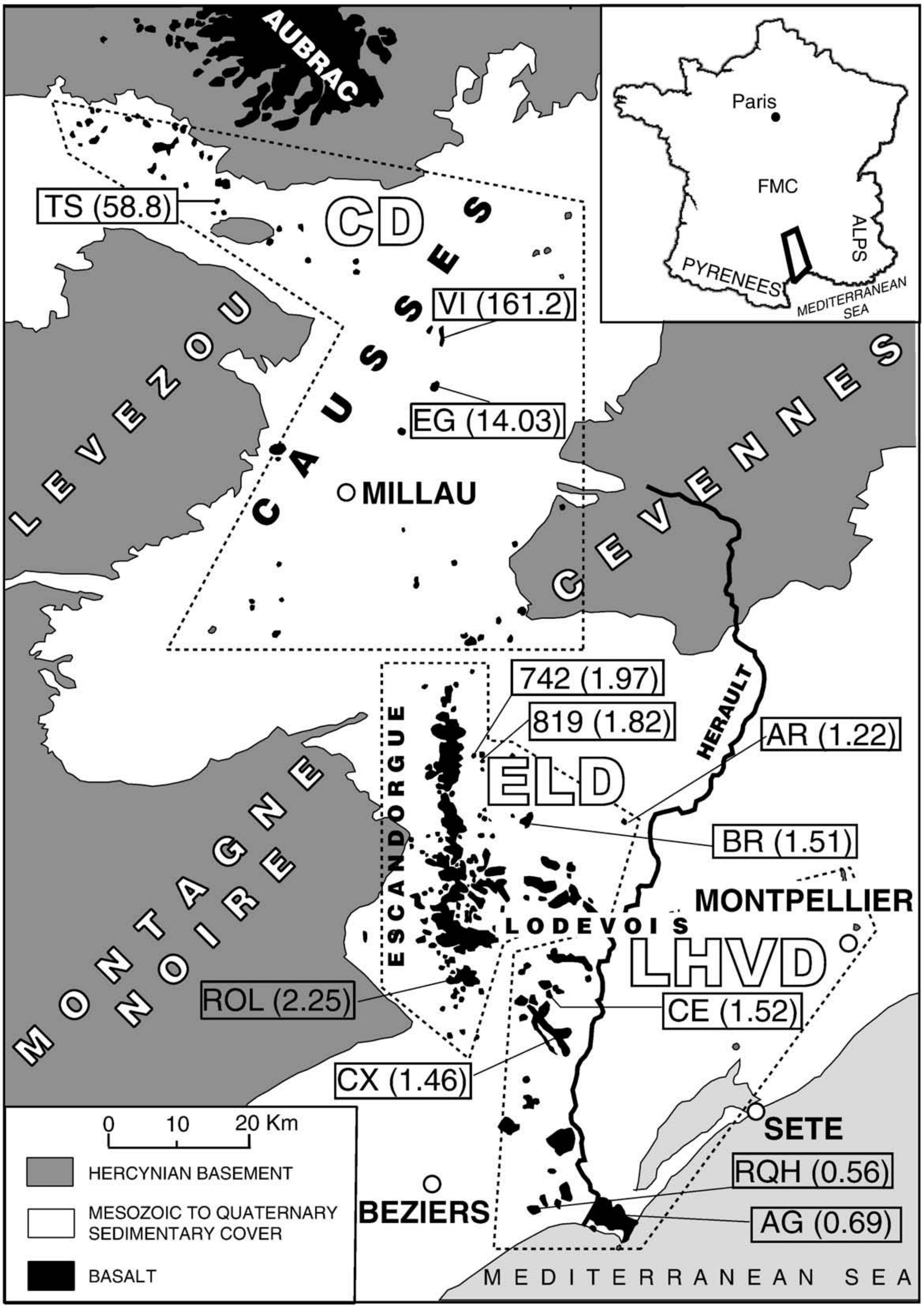

Fig. 1. Geological setting of Languedoc volcanic districts with locations and ages of samples dated in this paper. ROU: sample name (see Table 2), (): new age data (Ma) (see Table 1) CD: Causses district; ELD: Escandorgue-Lodévois district; LHVD: Low Hérault Valley District; FMC: French Massif Central. All volcanic rocks dated since 1974 and all samples analyzed for this paper are given in Fig. RM1.

side of the French Massif Central lithospheric swell, less than 200 km southwards of its apex.

The detailed study of the Languedoc basalts should thus bring new results that may answer many questions. Has the mantle sources of European basalts evolved during the last 160 Ma? Has it been affected by the compressive and distensive geodynamic events related to the Mesozoic and Cenozoic evolution of the Ligurian Tethys margin? Has it been modified by the opening of the Atlantic Ocean and the