9th International Kimberlite Conference Extended Abstract No. 9IKC-A-00255, 2008

Highly heterogeneous mantle sampled by rapidly erupted carbonate volcanism

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Calatrava Volcanic Province

The Calatrava volcanic province (CVP) comprises over 200 vents. All of the vents may have erupted carbonate rich volcanism, making it the largest extrusive carbonatite province known. Volcanism in Calatrava was active in the late Miocene to Quaternary (8.7-1.6Ma Lopez-Ruiz, 1993) associated with a period of rifting, postulated to be related to lithospheric relaxation following the Alpine-Betic orogeny.

The CVP is typical of many intraplate volcanic localities in and around Europe (see Lustrino & Wilson, 2007 for a review). However, many of the volcanics appear to differ in the composition to the traditionally identified undersaturated suite of rocks.

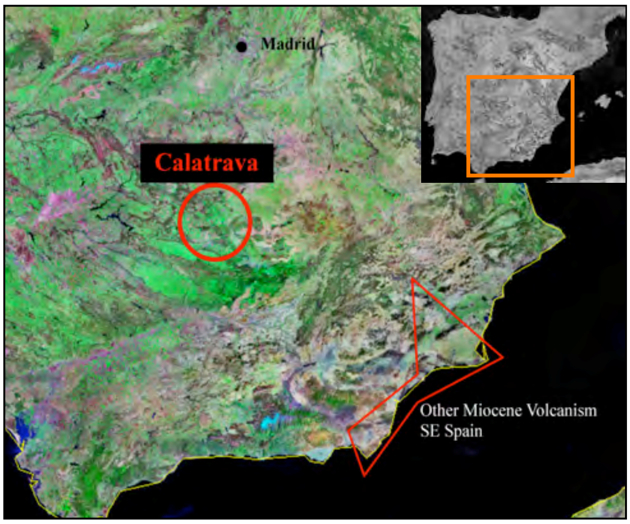

Fig. 1. Satellite image of the Iberian Peninsula. Red circle denotes the location of the Calatrava volcanic province. Madrid and other Miocene volcanics are detailed for comparison.

Although such rocks are abundant, other carbonate rich volcanics are present such as those identified from the Kaiserstul and Auvergne (Bailey et al, 2005 and references therein) which have not been previously described from this locality.

Many of the pyroclastic deposits, both carbonate rich or silicic, have entrained ultramafic material which is the focus of this study. Ultramafic nodules vary significantly, both from a single outcrop and between eruptive centres.

Ultramafic xenoliths

Xenolithic material is a common feature of these volcanics and pertains to their highly explosive nature. The most volumetrically abundant xenolithic material is that from the country rock, as is typical of explosive volcanic eruptions. Often ultramafic xenoliths are also present and in some cases may be more abundant than xenolithic country rock.

Fig. 2. An example of a large peridotite nodule erupted at Finca La Nava.

The ultramafic material from the CVP shows great diversity; displaying the whole spectrum of peridotite compositions. Mantle xenoliths are also often accompanied by material from the lower lithosphere.

Amphibole is an abundant xenocryst and occurs independently of any other type of ultramafic xenolith.

Volcanic centres

Work so far has focused on three main volcanoes which have erupted ultramafic xenoliths. Finca La Nava, the first locality, is a tuff ring deposit, found to have erupted peridotites, pyroxenites, and other ultramafic megacrysts. The second locality, Hoya de Nandin, is a scoria-rich tephra ring, surrounding a 700m diameter crater (maar). The outcrop consists of poorly sorted scoria and lapilli layers which are cemented by carbonates and zeolites. Upper crustal xenoliths of Ordovician quartzite (<50cm) are also common, but do not dominate. The third outcrop, Villa Mayor, is an olivine leucitite lava which contains peridotite xenoliths. Textural evidence suggests that the olivine crystals are out of equilibrium with the lava pertaining to a xenocrystic origin. Reaction rims are common and other disequilibrium features suggest a complex history for the lava. All of these localities exhibit volcanics which have erupted directly through ordovician basement and are not associated with tertiary limestones.

Finca La Nava

Ultramafic xenoliths at this locality are varied; peridotites are mainly wehrlitic and orthopyroxene-poor lherzolites, there are also lower crustal granulite facies rocks, such as spinel pyroxenite. Pargasitic amphibole and phlogopite are common constituents of the pyroclastic tuffs. Phlogopite is often found as small fragments (~0.5-2cm) within the matrix of the deposit. Amphibole crystals range in size from <0.5-5cm across, they often display very good cleavage or highly polished and pockmarked surfaces. Amphibole has been reported from peridotite xenoliths and phlogopite has also been noted. Glimmerite and hydrated xenoliths are documented from this locality and suggest a mantle metasomatic event, predating volcanism. Silicic lava is olivine melilitite in composition, however volumetrically it forms a small percentage of the outcrop, the tuff matrix is composed mainly of carbonate (Bailey et al., 2005).

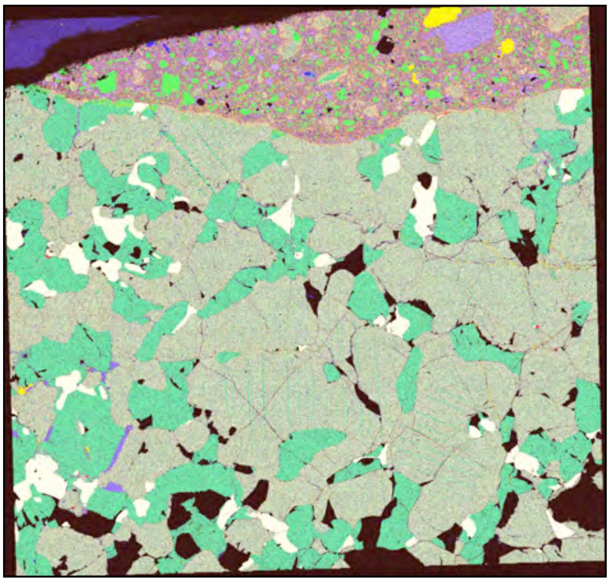

Fig.3. Element map of a Spinel-pyroxenite nodule, with associated lava, from Finca La Nava. Colours used are as follows; Aluminium – white, Magnesium – Green, Silicon – blue, Calcium – yellow, Iron – red.

Two samples, one of mantle origin and one of lithospheric origin have been analysed to determine general temperature and pressure constraints. The mantle sample is a phlogopite bearing wehrlite, ~60% clinopyroxene, 20% olivine and 20% phlogopite.

The lower crustal sample is a spinel pyroxenite (see fig.3), which has rare alkali feldspar and apatite. The presence of K-feldspar, sapphirine and prominent exsolution lamellae in the pyroxenes all pertain to the crustal origin of this sample.

Hoya de Nandin

Samples of ultramafic material at this locality are the most varied known from all of the volcanoes visited in the province. The silicic component of these volcanics is olivine melilitite. Peridotite nodules are varied, showing mainly wehrlitic compositions, but also lherzolites, dunite and harzburgite. Pyroxenites and pyroxene megacrysts have also been identified from this locality, along with a glimmerite sample.

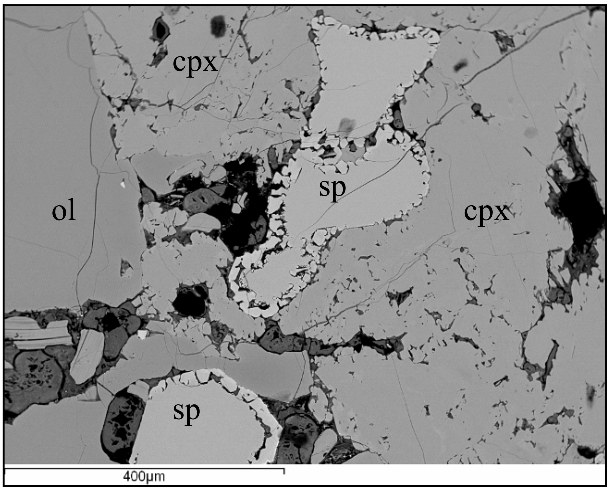

Fig. 4. BSE image of spinel in sample from a phlogopite bearing spinel wehrlite. Sp – spinel, cpx – clinopyroxene ol – olivine.

Figure 4 shows the texture of clinopyroxene and spinel in a sample of spinel wehrlite; spinel has a chromium rich rim and magnesium and aluminium rich cores.

Clinopyroxene is Chromium-rich with augitic cores and diopsidic rims.

A second sample, spinel lherzolite from the same locality shows little evidence of alteration of the main mineral phases. Orthopyroxene is aluminium rich enstatite and clinopyroxenes are generally diopsidic. Clinopyroxenes from the associated lava tend to be more calcic, but pyroxenes from the nodule and associated lava are all aluminous.

Villa Mayor

Massive olivine leucitite lava dominates this locality although there are some associated minor pyroclastics. Villa Mayor is the earliest example of volcanism in Calatrava, dated at 8.6-8.4 Ma. Xenolithic material is abundant in these lavas, however shows little compositional variation, being limited to spinel lherzolite. Olivine is very common in these lavas and is thought to be xenocrystic. Xenolithic material and associated reaction rims in this lava all suggest a complex history.

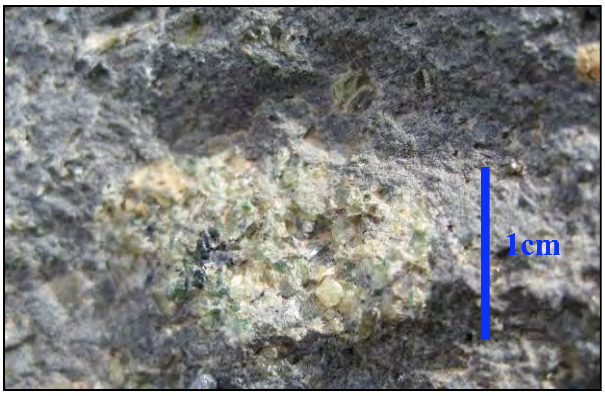

Fig. 5. Spinel lherzolite nodule within olivine leucitite lava.

Summary and further work

Significant variation of mantle material is observed from the CVP. Its association with lavas from different volcanoes in the province allows for further constraints on the origin and formation of continental intraplate volcanics.

Further work on this area consists of more comprehensive analysis of major minerals in the nodules and associated lavas. Isotopic analysis of nodules carrying metasomatic characteristics and associated melts is then planned in order to further constrain the origin and timing of metasomatism.

References

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