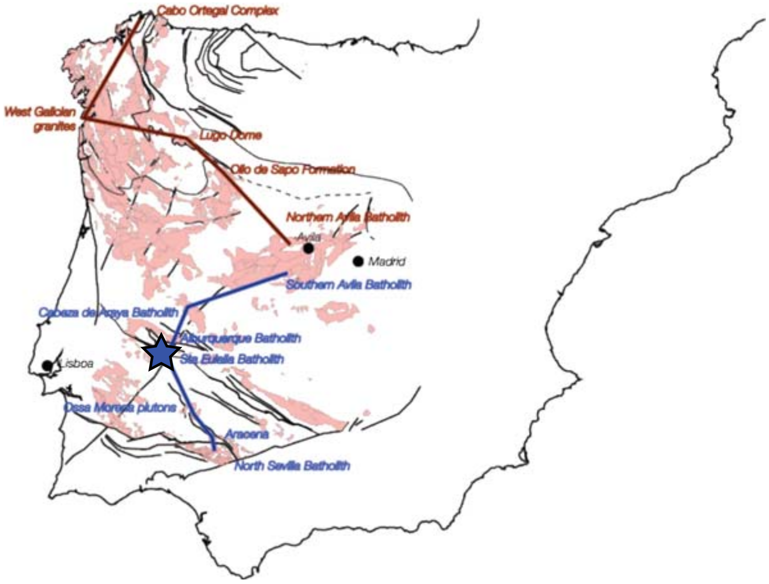
Day 3: 2nd July
Late Variscan Santa Eulalia Complex
and the Nisa-Alburquerque Batholith



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A. **Rita Solá** (LNEG, Apartado, 7586 2720-866, Alfragide, Portugal)

photo: Nisa-Alburquerque granite showing many metric size country rock xenoliths

Provisional Timetable

7.30	breakfast
8.00	depart Zafra
9.30	arrival at stop 1
10.30	depart stop 1
10.45	arrival at stop 2
11.15	depart stop 2
12.00	arrival at stop 3
12.30	depart stop 3
13.00-14.30	lunch at Castelo de Vide
15.00	arrival at stop 4
16.00	depart stop 4
17.00	arrival at stop 5
17.30	depart stop 5
19.00	arrival in Garrovilla

Late Variscan granitoid magmatism at both sides of a suture

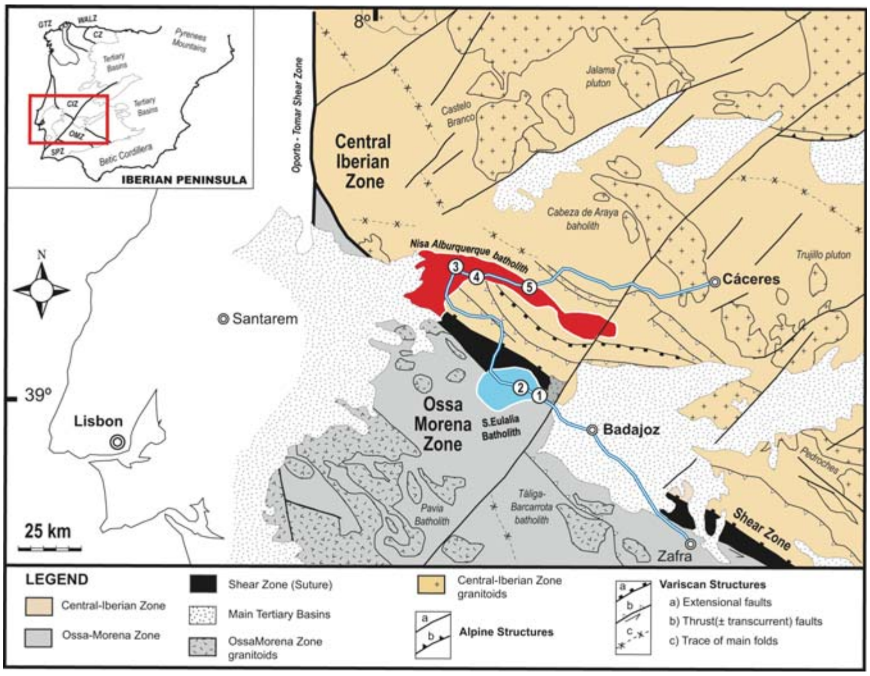


Fig. 3.1 Geological map of the Paleozoic igneous rocks in the Southern Iberian Massif (Central-Iberian and Ossa-Morena zones). The outlined Santa Eulalia pluton (blue) and the Nisa-Alburquerque batholith (red) are the targets of this field-trip.

The Santa Eulalia plutonic complex

Introduction

The Santa Eulalia pluton is an igneous complex of late Variscan age (Rb-Sr age ca. 280 Ma Pinto, 1984) emplaced in the northern part of the Ossa-Morena zone.

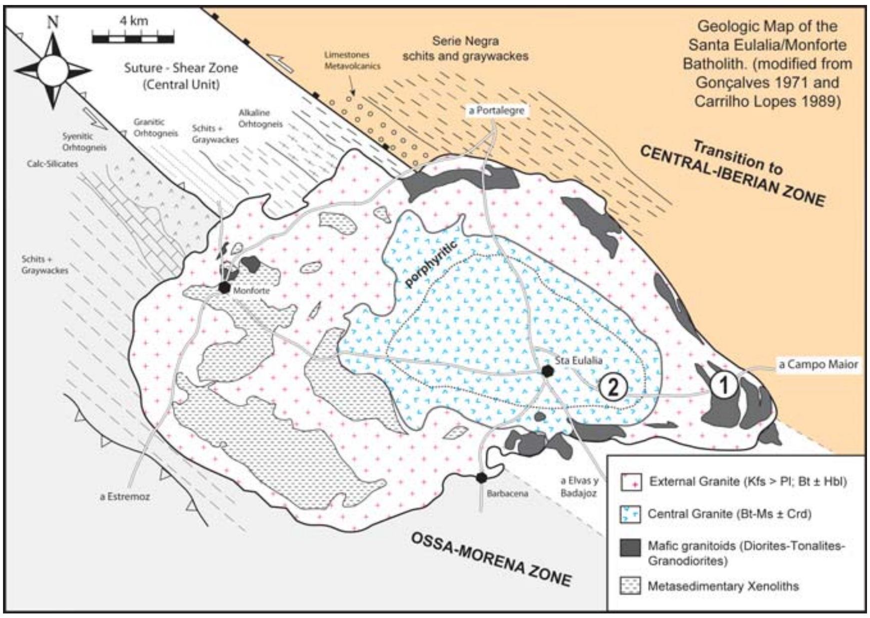


Fig. 3.2 Geological map of the Santa Eulalia pluton

Geochronology

The Santa Eulalia pluton has been dated by Pinto (1984) who obtained a Rb-Sr isochron age of 284 Ma.

Petrography

The pluton is formed of granitoids, mainly of I-type nature, that can be grouped into two units:

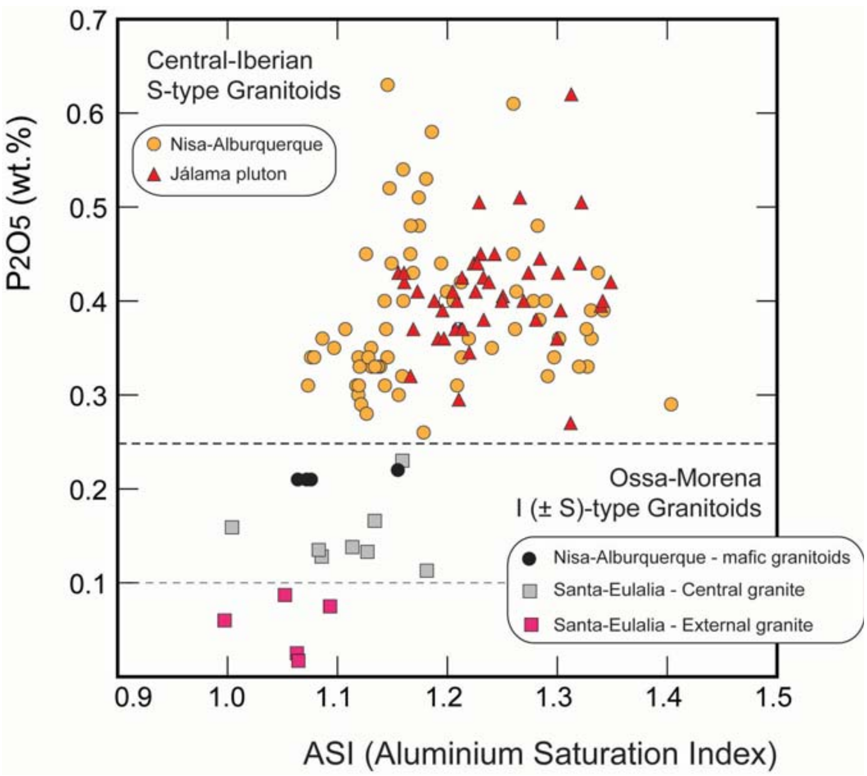
i. External unit: Kfs granites, pink colored granites, with Bt ± Hbl. These granites include enclaves of mafic igneous rocks, gabbro-diorite and tonalite-granodiorites, as well as country rock xenoliths.

ii. Central unit: Bt ± Ms granites, grey granites, with Pl > Kfs. Carrilho Lopes (1989) and Carrilho Lopes et al. (1998) have subdivided this central unit into different concentric facies according to its grain size.

Whole rock composition

The mafic rocks of this pluton,SiO_2 ≈ 47-68 wt.%, have variable Mg# 32-61 and ASI values 0.61-1.09, and most have negative anomalies of Ba, Nb, Sr and Ti relative to primitive mantle values. Despite these similar features some variation trends Zr vs SiO_2 and element ratios Nb/La indicate a different petrogenesis for the gabbro-diorites and the tonalite-granodiorites. Regarding the granites, the external ones have low ASI values 0.99-1.05 and low contents in CaO 0.48-1.43 wt.%, P_2O_5 0.02-0.09 and Sr 2-90 ppm. On the other hand, the central granites have higher ASI values 1-1.18 and higher contents in CaO 1.6-2.15 wt%, P_2O_5 0.11-0.23 wt% and Sr 170-220 ppm.

Fig. 3.3 P_2O_5 versus Al saturation index for the Santa Eulalia and Alberquerque rocks



Stop 1:- Santa Eulalia - Caia Dam–Campo Maior: external Kfs (± Pl) granite and mafic granitoids (granodiorite ± leuco-tonalites)

UTM, 29, WSG84: 660511 4318013

38º 59’ 41.7’’ N 7º 8’ 47.4’’ W

Field relations and petrography

In this first stop we will observe the external granite of the Santa Eulalia pluton in contact with mafic-intermediate rocks, granodiorites-leucotonalites, and with calc-silicate xenoliths (Fig. 3.4).

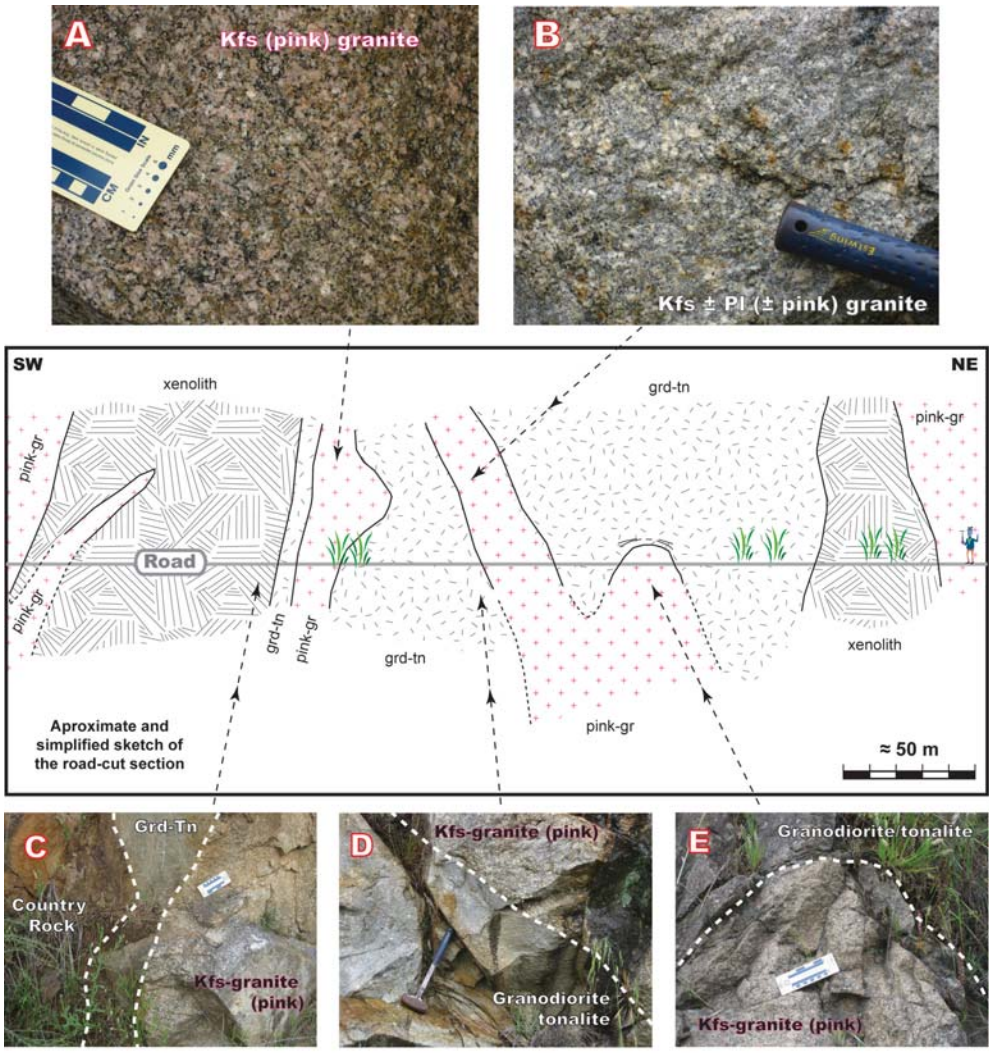


Fig. (...) Simplified field sketch of the road cut in the stop 1 (Caia Dam Reservoir) in the Santa Eulalia igneous complex.

Fig. 3.4 Field sketch of stop 1 (a and b) Kfs granite (c) country rock xenolith intruded by the granitoids, d) intermediate rocks, granodiorites, (e) contact relations suggest that Kfs granites intruded other igneous rocks

Starting this road-cut, on the north-side, from the east towards the west we can see the external granite with Kfs + Pl. Other minerals are Bt, visible in the outcrop, and much less abundant Hbl. Walking towards the west, this external granite intrudes a dark calc-silicate country rock, ± amphibolites(?), with round-globular shapes. Further to the west a fine grained granodiorite, ± leuco-tonalites formed mainly by Qtz + Pl + Bt ± Hbl intrudes the calc-silicate rock. Some 30m to the west, we can observe a possible intrusion of the external Kfs granite into the granodiorite/leuco-tonalite. These field relations could indicate that the granodiorites were the first to intrude into the calc-silicate country rocks and afterwards the external Kfs granite intruded both the granodiorites and the country rock. In other studied zones, partial mixing between the external Kfs granitoids and the granodiorites was observed.

Stop 2:- Santa Eulalia - Caia dam – Almeida Velha: Central unit

UTM, 29, WSG84: 654779 4318332

39º 0' 1.1'' N 7º 12' 45.3'' W

Field relations and petrography

The Central unit is a Bt-bearing granite with Pl > Kfs, that also has also some primary Ms (Fig. 3.5).

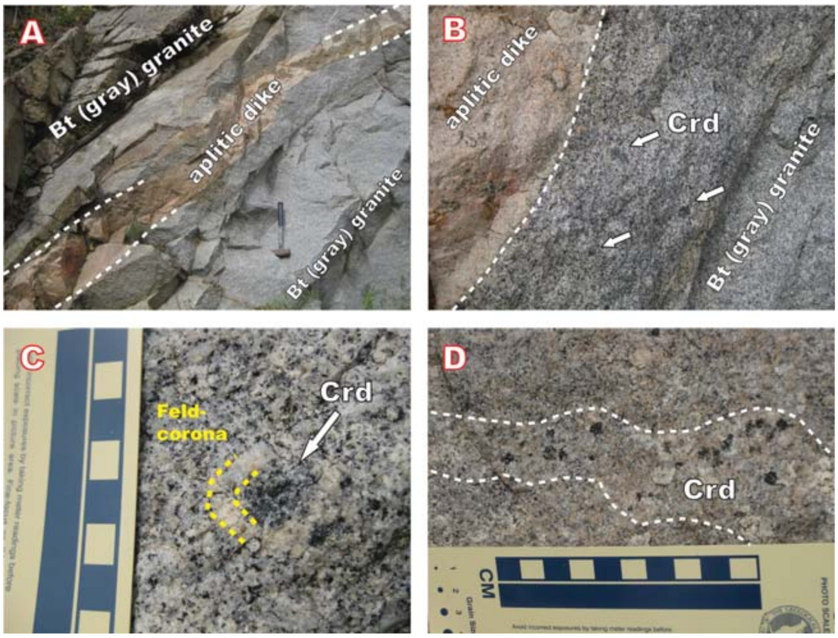


Fig. 3.5 (a and b) the Central unit is cross-cut by a pink aplitic dyke (b, c and d) cordierite is scattered through the rock, (c) some of these crystals show a corona structure composed of feldspars or (d) occur within more leucocratic domains

In this outcrop there is a Kfs-rich aplitic dyke. One interesting feature is the probable presence of cordierite, a somewhat infrequent mineral in this kind of Ossa-Morena zone granitoid. Cordierite in this outcrop is altered to pinnite and occurs in two different textural/mineralogical forms:

i. as disseminated mineral grains within the Bt-granite, in some cases having a feldspar outer corona, and

ii. surrounded by leucocratic zones. In any case, these crystals seem to have special textures different from the other minerals constituting the rock, Qtz, feldspars, Bt, Ms

Petrogenetic model

The petrology and geochemistry of the different igneous units of the Santa Eulalia plutonic complex suggest that were coeval but with independent petrogenesis (González Menéndez et al., 2006). The more mafic rocks, gabbros-diorites, were probably derived from an enriched mantle affected by previous subduction processes. The intermediate mafic rocks, tonalites and granodiorites, have a very variable geochemistry and are thought to be the result of partial melting processes of a lower mafic crust. The Kfs granites of the External unit were probably generated by partial melting of intermediate gneissic rocks in the mid-lower crust, whereas the grey Bt-granites of the Central unit probably have a mixed source of metasediments, S-component, and intermediate to acid igneous rocks, I-component, from the mid-lower crust.

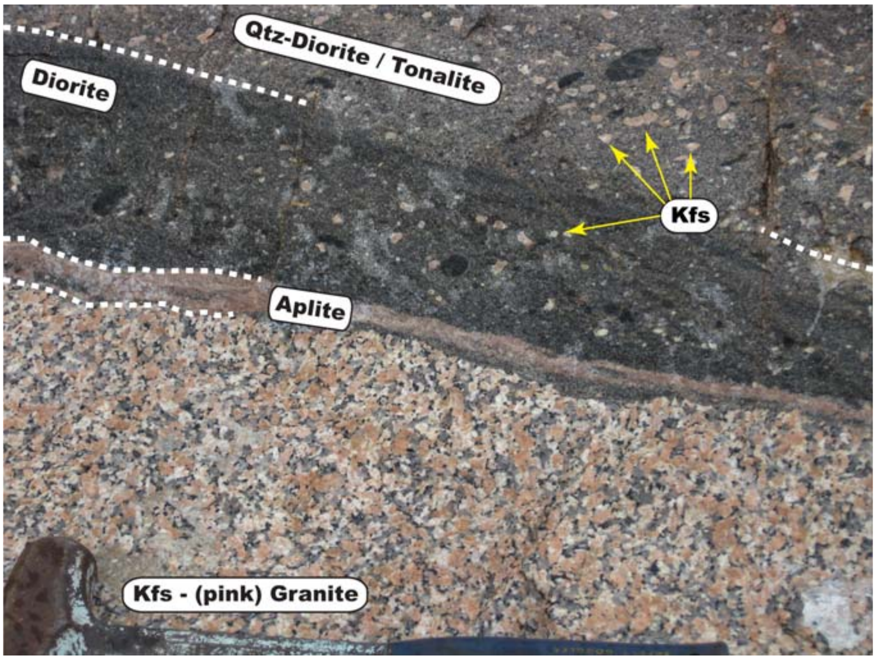


Fig 3.6 Contacts and possible partial mixing between the External granite and mafic rocks.

The Nisa-Alburquerque Batholith

Introduction

The Nisa-Alburquerque batholith is a composite intrusion of late Variscan age, 294-306 Ma (González Menéndez, 1998 and 2002; Solá, 2007; Solá et al., 2009) formed by different granitoid units, mostly with sharp contacts or transitional within a few meters, that can be grouped into dominant S-type granites and minor I-type granitoids (Fig. 3.7).

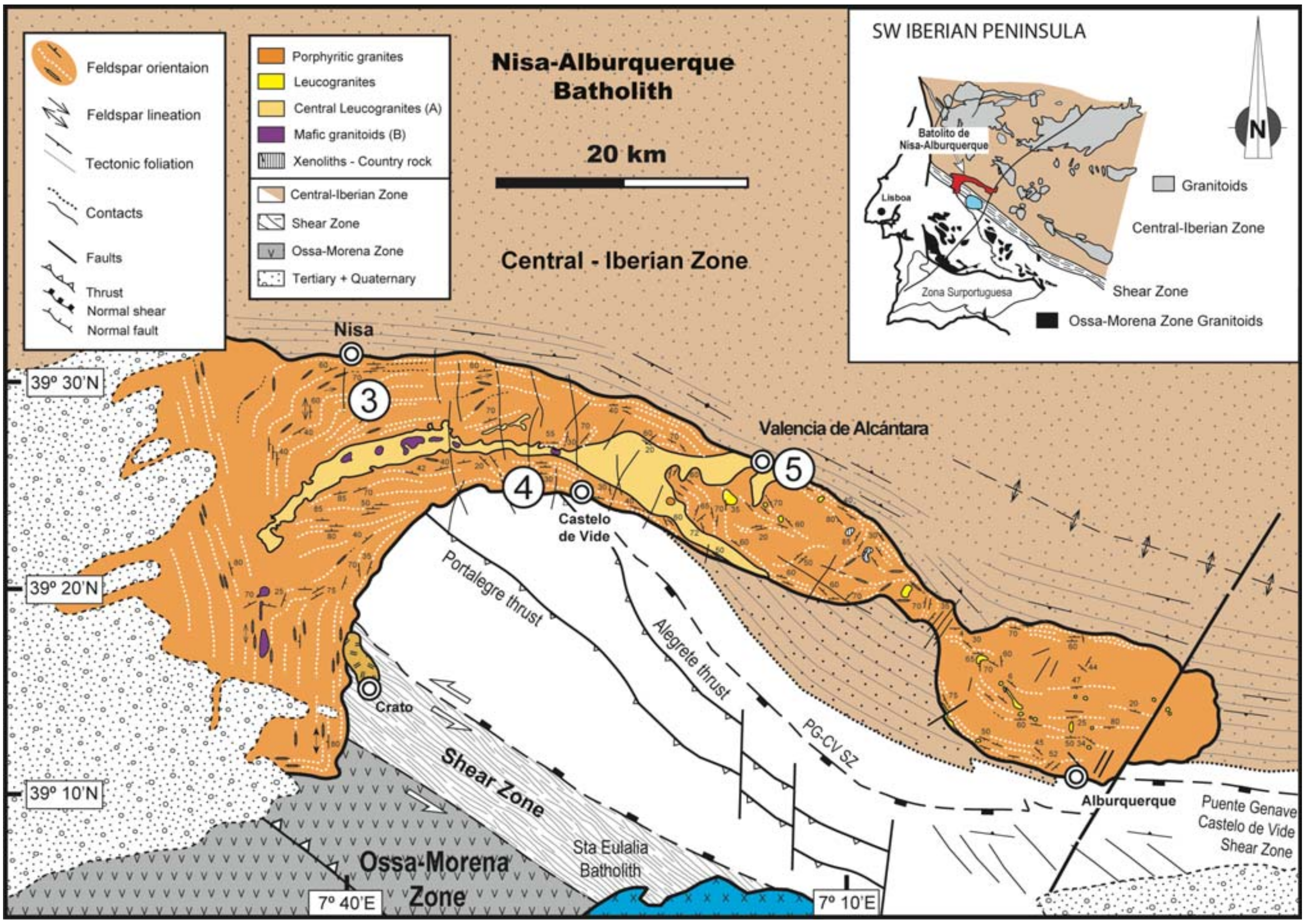


Fig. 3.7 Geological map of the Nisa Alburquerque batholith. Country rock geology simplified.

Geochronology

The Nisa-Alburquerque batholith has been dated by various authors in the past decades. The most recent data are from González Menéndez (1998 and 2002) a Rb-Sr isochron age of 294 ± 11 Ma (MSWD = 1.12); and Solá et al. (2009) who obtained SHRIMP $^{206}Pb/^{238}U$ ages of 309 ± 4.6 Ma, mean age of the youngest zircon cores, and 307.4 ± 4.0 Ma, mean age of zircon overgrowths, for the main porphyritic granite unit.

Petrography

S-type granites constitute the main granites forming the batholith and include:

i. porphyritic Bt + Ms ± Crd ± And ± Tur monzogranites and leucogranites that usually define Kfs + Pl magmatic orientations which are especially intense towards the western zones of the batholith.

ii. central leucogranites, Gafete granites, with Bt + Ms. In some locations some Tur + Crd + And are present, possibly related to interaction with the porphyritic granites.

iii. leucogranites of fine grain size forming small bodies within the porphyritic granites.

iv. aplite and pegmatite dykes within the porphyritic granite, usually cutting the magmatic fabric. In some locations small aplite segregates are present that could be residual melt segregations from the porphyritic magma.

I-type granitoids are composed of tonalites-granodiorites, Bt + Amp + Tnt, and monzogranites, Bt, or Bt ± Ms, that form small to intermediate size bodies within the S-type granites, porphyritic and Central leucogranite. Contacts are sharp but in some locations there is evidence of mixing with the S-type granites.

Whole rock composition

The S-type granitoids, granites and leucogranites, of the batholith are characterized by a strong peraluminous nature, ASI ≈ 1.05-1.35, high K_2O contents 3-6 wt.%, P_2O_5 0.25-0.6 wt.% and low CaO 0.1-0.6 wt.%, Sr ≤ 100 ppm and Zr ≤ 100 ppm. Crustal isotopic signatures are $^{87}Sr/^{86}Sr_i$ 0.7105-0.7176.

The I-type granitoids, tonalites-granodiorites-monzogranites, have lower ASI values 0.97-1.15 and lower P_2O_5 contents 0.2-0.25 wt.%, but higher contents in CaO 1.3-2 wt.%, Sr 160-200 ppm and Zr 150-180 ppm. The isotopic signature also shows remarkable differences: $^{87}Sr/^{86}Sr_i$ 0.7053-0.7068.

Stop 3:- Nisa-Alburquerque batholith - Alpahao – Nisa: porphyritic (S-type) peraluminous granite

UTM, 29, WSG84: 617315 4370610

39º 28' 37.5'' N 7º 38' 9.6'' W

Field relations

At this locality we observe a general view of the main granitic unit of the Nisa-Alburquerque batholith: the peraluminous porphyritic granite, Bt + Ms ± Crd, with its 60º-80º oriented magmatic Kfs ± Pl fabric. These orientations are parallel to the major external, country-rocks, and internal contacts, central leucogranite. There are small domains with a slight different orientation but without any internal contacts among them. This magmatic fabric is more intense, better defined, in the western locations, whereas towards the east the porphyritic granite becomes more isotropic. One possible explanation for this change could be the smaller size of the magma chamber in this western domain, as deduced from gravimetric studies, combined with the later intrusions of the central granites A and B, which could have caused some tightening of the magma phenocryst framework towards the external contacts of the batholith (González Menéndez and Azor, 2006).

Stop 4:- Nisa-Alburquerque batholith - Castelo de Vide – Portalegre: aplitic “melt” segregates

UTM, 29, WSG84: 630613 4364785

39° 25’ 21.7’’ N 7° 28’ 57.3’’ W

Field relations

Aplitic dykes usually cross-cut the fabric of the porphyritic granite. How these aplitic melts segregate from the main magma and escape to form intruding aplitic dykes is shown in this outcrop of the porphyritic granite: irregular aplitic pods align parallel to the magmatic fabric and show transitional contacts. These aplitic pods or segregates have a mineralogy of Qtz + Ab>Or + Bt + Ms. Some of the phenocrysts from the porphyritic granite, Kfs ± Pl ± Crd ± Bt, are incorporated into the melt segregates. The possible explanation for this melt segregation process would be the solidification of the porphyritic magma mush when the Kfs ± Pl fabric formed, causing squeezing of residual melts. The geochemistry of these melt segregates is more evolved than that of the porphyritic granites, but less evolved than the aplitic dykes (Fig. 3.8) and could be interpreted as aplitic melts in their initial stage of development.

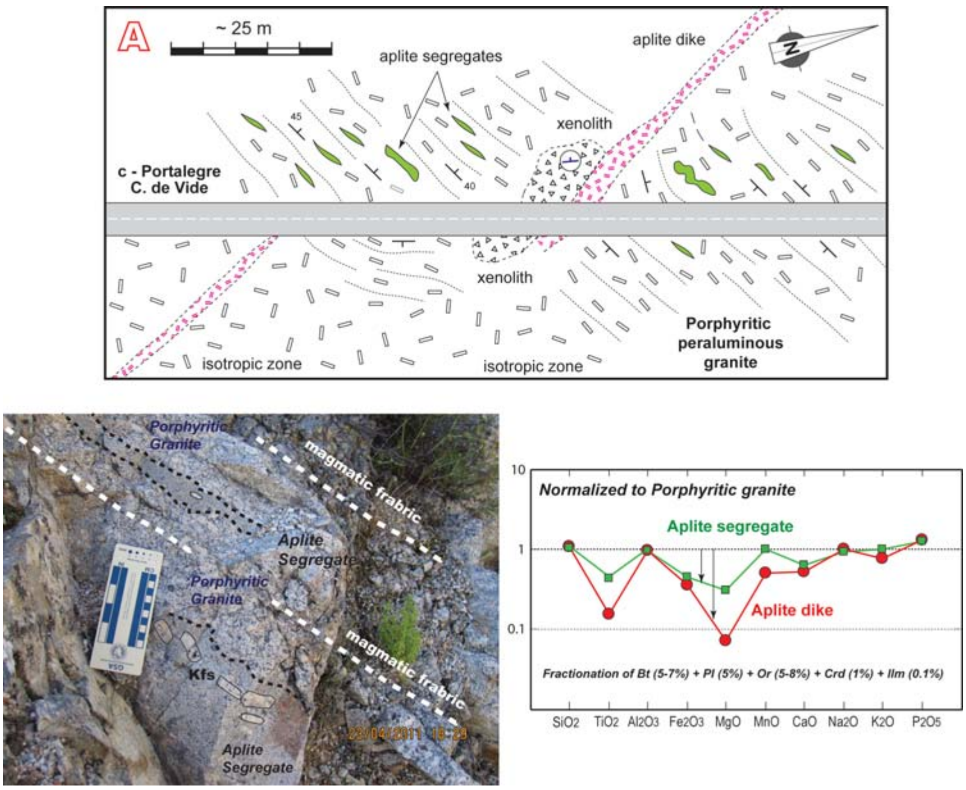


Fig. 3.8 Geological sketch of stop 4. Segregates, with entrained Kfs ± Bt from the porphyritic granite, were formed by fractionation of Bt+Pl+Kfs+Crd+Ilm from a porphyritic magma

Stop 5:- Nisa-Alburquerque batholith - Valencia de Alcántara: Central leucogranite

UTM, 29, WSG84: 651584 4363239

39º 24’ 19.2’’ N 7º 14’ 21.9’’ W

Field relations

The central leucogranite at its eastern end, close to the contact with the porphyritic granite, is somewhat Kfs-porphyritic, of medium grain size and formed by Bt + Ms plus other index minerals such as Tur ± Crd altered to pinnite. In the western locations the central leucogranite is more equigranular and shows a simpler mineralogy consisting of Bt+Ms ± Tur. This change in texture and mineralogy towards the east could have been caused by partial mixing with the porphyritic granite that would have transferred Kfs ± Crd. The central leucogranite is intruded at this outcrop by a fine- to medium grain size Tur-leucogranite dyke. The leucogranite dyke also shows pale-to dark-brown halos indicative of possible altered sulphides.

Petrogenetic model

The petrology and geochemistry indicates that the S-type granites are mainly derived from metapelitic ± metagreywacke sources mixed with a minor I-type component, whereas the I-type granites are possibly related to amphibolitic-tonalitic sources (González Menéndez, 1998 and 2002; Solá, 2007 and Solá et al., 2009).

Concluding remarks

The Santa Eulalia and the Nisa-Alburquerque intrusions are representative of the late Variscan magmatism in two different tectonostratigraphic zones: Ossa-Morena and Central-Iberian. Both intrusions are consistent with melting and recycling of the continental crust as well as possible magma mixing processes. The magmatism of the Santa Eulalia complex involved important amounts of mafic-intermediate melts and the granitic melts produced were I-type with relatively minor S-type component. This suggests an important involvement of mantle-derived components in the source of Ossa-Morena Variscan granitoids. On the other hand, the magmatism from the Central-Iberian zone, Nisa-Alburquerque batholith, involved less mafic-intermediate melts and S-type granitoids predominant, indicating important melting-recycling processes in the continental crust. This comparison suggests substantial differences in basement composition and/or melting processes between Ossa-Morena and Central Iberian zones.