INTRODUCTION

The Montnegre Masseif is part of the Catalan Coastal Ranges, extending 60 km NE from Barcelona and outcropping over an area of about 550 sq.km. (Fig. 1). Both the Catalan Coastal Ranges and the Pyrenean Axial Zone form the main Hercynian outcrops in the NE of the Iberian Peninsula, whose principal features were described by JULIVERT et al. (1980) in Newsletter 2 of IGC Project No. 5, and Guide to Field Trips in the Eastern Pyrenees and Catalan Coastal Ranges (1981, IGC Project No. 5).

The Catalan Coastal Ranges are considered to be a fragment of the southern branch of the Hercynian orogenic belt. Together with the Pyrenean Axial Zone and the Montagne Noire, these ranges are thought to be an eastward prolongation of the West Asturian/Leonese...

Fig. 1: Geological map of Montnegre Masseif: plutonic rocks. Numbers are explained in the text and figures.

SASSI & JULIVERT, IGC Project No. 5 NEWSLETTER Vol. 6 (1986)
Zone (JULIVERT, 1979; JULIVERT & MARTINEZ, 1983). It should be noted, however, that there are several differences between them.

Most of the Paleozoic outcrops of the Catalan Coastal Ranges are formed of a very important series of post-tectonic plutonic intrusions, mainly of granodiorite, tonalite and monzogranite compositions, although some diorites, gabbroids, and ultramafic rocks also exist in lesser amounts.

An important porphyritic microgranite, microgranodiorite and microdiorite dyke swarm exists associated with the plutonic rocks. In the northern part (Costa Brava) felsite masses and dikes, sometimes with a hypolithic aspect, become increasingly prominent.

All the intrusive rocks studied display calc-alkaline affinities and the main rock-types are biotitic or hornblende-biotitic. In the southernmost outcrops, some orthopyroxenes sometimes occur.

With regard to the age of the intrusions in the Catalan Coastal Ranges, geological evidence shows that they are post-Visean (JULIVERT & MARTINEZ, 1981) and pre-Triassic.

On the other hand, it should be noted that in the Southern Pyrenees calc-alkaline volcanic rocks outcrop widely. They are composed of basaltic andesites, andesites, dacites, and rhyolites (often ignimbritic) (GISBERT, 1981; POGA & FONTBOTE, 1979; MARTI, 1982), ranging in age from Stephanian to Permian. These rocks might have a petrogenetic relationship with the Pyrenean post-tectonic granitoids of similar emplacement age (GISBERT, 1981).

In the Catalan Coastal Ranges, however, no sediments younger than Visean have been preserved, so any possible genetic relationship between plutonism and volcanism remains speculative.

Almost all the granitoids of the Catalan Coastal Ranges intruded into very low-grade metamorphic materials, displaying sharp contacts with the enclosing rocks and inducing a thermal metamorphism aureole. In addition to the existence of abundant miarolitic cavities in some granitoids, these facts suggest a high-level emplacement of the plutonic rocks. According to the above features, these rocks seem to be similar to the Iberian Massif calc-alkaline granitoids considered by CAPDEVILA et al. (1973) as hybridized granitoids of infra- or basi-crustal origin.

Likewise, they are similar both to the Pyrenean granitoids "en masses supérieurs" (ADTRAN et al., 1970), and also to the late-Hercynian batholiths from Corsica and Sardinia (DI SIMPLICIO et al., 1974; BRALIA et al., 1983).

Finally, it may be noted that, in opposition to the Iberian Massif and the Pyrenees, autochthonous and para-autochthonous granites linked to regional metamorphisms are very scarce, although small stocks such as the Oeur syntectonic muscovite leucogranite are known (CURAY, 1981).

PETROGRAPHIC DATA

The plutonic rocks from the Montnegre Massif show a wide compositional range varying from leucogranites to hornblende granites, although granodiorites are by far the most important types. From the petrographical and geochemical points of view, it seems possible to differentiate two groups, separated partly by a band of Paleozoic materials (Ordovician, Silurian, Devonian, and Lower Carboniferous). This band is roughly elongated in an E-W direction where the highest topographical point in the Massif (Montnegre, 757 m) is situated. These Paleozoic materials are intruded by the granitoids, with the development of a prominent contact metamorphosis aureole surrounding them. In this aureole are several hornfels varieties containing cordierite, chlortolite, diopside, garnet, idocrase, wollastonite, and other metamorphic materials.

The plutonic rocks south of the Paleozoic materials form a group of somewhat homogeneous plutons. Most of the contacts between them are sharp; others seem to be gradational, although this has not yet been proven due to the slight compositional variation among some types and their intense weathering.

The Southern Montnegre plutons are formed of the following petrographic types:
1. Hornblende-biotite gabbrodiorites (very small outcrops);
2. Heterogranular hornblende-biotite metatolites (small outcrops);
3. Hornblende-biotite tonalites;
4. Biotite tonalitic granodiorites with accessory hornblende;
5, 6, 7. Biotite granodiorites;
8. Biotite leucogranites, and muscovite-biotite leucogranites (sometimes with accessory garnet).

The Northern Montnegre plutons are smaller in area and are composed of the following types:
9. Ultramafic rocks with coticlaticitic affinities: olivine hornblende (very small outcrops);
10. Gabbro bodies of biotitic composition (calcic plagioclases and amphiboles);
11. Pyroclastic hornblende-biotite diorites;
12. Porphyritic biotite granodiorites (with K-feldspar megacrysts);
13. Muscovite-bearing biotite granodiorites;
14, 15, 16. Pink biotite granites.

The petrographic nomenclature is based on

![Fig. 3A: Average compositions of main mapped plutonic types plotted in QAP (STREIKEISEN, 1976) diagram. Symbols as in Fig. 6.](image)

![Fig. 3B: Plot in OL-PL-HB (STREIKEISEN, 1976) diagram of ultramafic type ("comitalllite").](image)

STREIKEISEN (1976) (Fig. 3) and DE LA ROCHE et al. (1980) (Fig. 4). Both classifications generally coincide, although some differences exist, mainly in the most basic types.

PLUTONIC ROCKS

Southern Montnegre

1. Hornblende-biotite gabbrodiorites. There is a small outcrop W of Doans, near the contact between granodiorites (5) and tonalites (3). The rock is medium-grained, dark, and rich in biotite and hornblende, with small
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Table 1: Average major-element analysis and CIPW norms of Montnegre Massif described in text. Numbers in text and figures.

amounts of quartz. The main mineral is a quite highly calcic hypidiomorphic and zoned plagioclase.

2. Heterogranaular hornblende-biotite melatones. There is a group of small outcrops N of Telín surrounding Mt. Sant Mateu (490 m). These rocks are dark grey and heterogranaular with large hornblende crystals (up to 2 cm long), biotite and plagioclase. The groundmass is granular and medium to fine-grained containing the same minerals as the large minerals described above, in addition to quartz. The plagioclase is hypidiomorphic and strongly zoned, often revealing patchy zoning. These rocks are in contact with the tonalites with which they seem to have co-existed in the magmatic state: they show smooth sinuous contacts; they are both recitiprocally enclosed as enclaves; a narrow hybrid zone between them is sometimes present.

3. Hornblende-biotite tonalites ("Sant Mateu Tonalites"). These rocks cover a large area in the southern part of Montnegre in a continuous outcrop, elongated from SW to NE. They are light grey in colour and rather course-grained, and the existence of some large idiomorphic hornblende crystals (up to 2.5 cm long) gives a heterogranaular appearance to the rock. Biotite also forms idiomorphic crystals with pseudo-hexagonal habit, often reaching 1 cm in length. Plagioclase tends to be idiomorphic, while K-feldspar (orthoclase and microcline), very often interstitial, forms poliklinitic plates with very irregular borders, and includes small idiomorphic crystals of plagioclase and biotite.

Examination of thin sections shows that the rock consists chiefly of idiomorphic to hypidiomorphic plagioclase, strongly zoned, with oscillatory and patchy zoning. The anorthite content of the plagioclases is high, ranging from labradorite (in some crystal cores) to oligoclase, although Ca-rich anesine is the most frequent composition. The plagioclase crystals are generally twinned on the Albite Law and more rarely on the Pericline and Carlsbad Law. Synenesis on several plagioclase crystals may sometimes be seen. The more calcic zones of the plagioclase are usually at least partly altered.
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| C | 0.65 | 1.48 | 1.14 | 1.34 | 0.86 | 0.11 | 0.53 | - | 1.69 | 0.65 |
| Ab | 29.02 | 30.03 | 31.30 | 28.36 | 27.07 | 23.18 | 19.79 | 27.07 | 27.66 | 21.30 | 35.02 |
| An | 13.53 | 10.86 | 6.30 | 8.97 | 16.42 | 24.05 | 30.40 | 29.32 | 27.40 | 34.52 | 12.55 |
| K | - | - | - | - | - | - | - | - | 5.01 | - |
| D | - | - | - | - | - | - | - | - | - | 0.00 |
| Na | 3.26 | 2.20 | 1.60 | 2.24 | 4.07 | 8.09 | 17.18 | 14.62 | 11.62 | - | 3.51 |
| M | 0.05 | 0.58 | 0.39 | 0.36 | 0.93 | 1.46 | 1.40 | 1.76 | 1.65 | 1.99 | 0.70 |
| Ax | 32 | 27 | 17 | 23 | 38 | 51 | 61 | 52 | 50 | 62 | 26 |

Into sericite; in addition, some clinozoisite may be formed.

K-feldspar (generally microperthitic) is present in minor amounts and often shows the cross-hatched twinning of microcline. On the other hand, there are occasionally some symmorphic intergrowths between plagioclase and K-feldspar. Quartz is abundant as allo-tronormorphic poly-crystalline aggregate, generally showing undulatory extinction. Biotite, also present in considerable amounts, displays an intense brown to yellow pleochroism, and contains many inclusions of idiomorphic prismatic apatites. It also contains idiomorphic zircons, small idiomorphic plagioclases, and ore minerals in lesser amounts. A hypidiomor-
phic, sometimes twinned hornblende is present in smaller amounts, showing a strong green pleochroism, and including some apatites and zircons. Many melanocratic inclusions with apparently homogeneous distribution in the overall outcrop are contained in the tona-
lites. They are generally microgranular en-
claves (DIDIER 1973) of quartz-dioritic com-
position (see Tables 1 and 2, no. 22). Their
size is variable, normally ranging between 20
and 30 cm. They are usually rounded and a pro-
gressive change in composition and grain-size

A complete changing sequence from pelitic
Table II: Modal compositions of main rock-types of Montnegre Massif. Numbers as in text and figures.

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Q 26.30 33.57 37.98 38.14 36.92 - 0.91 13.13 37.77 37.67 32.35 12.89
A 2.04 6.67 7.37 14.75 31.13 - 0.60 2.64 20.15 25.76 33.40 5.45
P 71.66 59.75 54.66 47.10 31.94 - 98.48 84.23 47.06 36.57 35.25 81.66

Table II: Modal compositions of main rock-types of Montnegre Massif. Numbers as in text and figures.

Fig. 4: Average compositions of main plutonic and hypabyssal types and enclaves plotted in R2 (DE LA ROCHE, 1980) diagram. Symbols of plutonic rocks as in Fig. 6. Small circles: hypabyssal rocks; open stars: enclaves.

Fig. 5: Average compositions of main plutonic and hypabyssal rocks plotted in A-8 (DEBON & LE FORT, 1983) diagram. CAK: calc-alkaline trend from French and Spanish Pyrenees; THK: tholeiitic (plutonic) trend from Sparta Complex (Oregon) (DEBON & LE FORT, 1983).
hornblende to migmatic rocks (formed by induced anatexis) and serpentaceous enclaves may be found, the latter representing the restites in the most evolved states (BIDIER, 1973).

4. Biotite tonalitic granodiorites with accessory hornblende ("llavaneres Tonalitic Granodiorites"). These rocks outcrop quite extensively on the coastal slope of the Massif, between the towns of Mataró and Arenys de Mar. They have similar features to the tonalites described above, but differ in that they are richer in K-feldspar and have little and less apparent hornblende. They are rather coarse-grained and contain abundant quartz-dioritic microgranular dark enclaves, bearing biotite and hornblende.

A noteworthy feature is the common occurrence of allanite as an accessory mineral sometimes reaching 1 cm in length and 2 mm in width. Contacts of the rocks with the hornblende-biotite tonalites are not clear and may be gradational.

5. Medium-grained biotite granodiorites ("Or-Plus Granodiorites"). These granodiorites represent the most abundant granitic rocks in the Montnegre Massif, distributed in several
isolated outcrops. They seem to intrude into the tonalitic granodiorites and tonalites, firstly due to their sharp contacts, and secondly to the existence of some granodiorite dykes thrown out into the latter two rock types.

Paleozoic materials (mainly Cambro-Ordovician) are sharply intruded by these granodiorites. Big stoped and rotated hornfels blocks may sometimes be found near the contacts, but in most cases only minor piecemeal stoping may be observed. These granodiorites are finer-grained (3-4 cm) than the rock-types described above, and their dark microgranular enclaves (Fig. 4, no. 25) are usually scarce and small (5-15 cm). Some metamorphic enclaves also exist, and one of them, almost exclusively composed of sillimanite, has been found.

These have a lower colour index than tonalitic rocks and do not contain hornblende, although it can occur rarely as an accessory. K-feldspar is relatively abundant in allotriomorphic and poikilitic plates including biotite and plagioclase. Biotite displays a prismatic habit.

In this thin section they show dominant plagioclase and quartz, the former being hypidiomorphic-idiotrophic and strongly zoned. Athlitrophic K-feldspar and hypidiomorphic biotite are also quite frequent. Idiomatic apatites and zircon are usually included in biotite.

Two different granodiorites outcropping in smaller areas have also been mapped. They are lower in colour-index and richer in K-feldspar than the normal biotite granodiorite. Some of their features are as follows:

6. Fine-grained heterogranular biotite granodiorite. These rocks are mainly characterized by their fine grain-size and by two different habits of biotite (prismatic and flaky). They also present some plagioclase and biotite larger than normal.

7. Biotite granodiorites with flaky biotite. These rocks are granular, medium-grained, and do not contain prismatic biotite.

8. Biotite leucogranites, and muscovite-bearing biotite leucogranites (sometimes with accessory garnet). ("Célices-Hurrian-Carredor Leucogranites"). In contrast to grey granodiorites and tonalites, a group of whitish rocks is present in relatively small outcrops (1-3 km maximum diameter). These outcrops stand out against the average topographic surface because of their resistance to erosion.

These rocks have monzogranitic composition and bear some biotite, although in most samples this mineral is less than 5%; they are therefore considered as leucogranites.

They show important variations in grain-size and biotite content, and this mineral may be totally absent in some places. Likewise, they may give way to amphibolites or pegmatites, often over very short distances.

Near the orders or at higher-level positions, the plutons may change towards a fine-grained facies, usually with little muscovite, and occasionally some garnet. The medium-to coarse-grained biotitic types may include a few dark microgranular or metamorphic enclaves (the latter very micaceous and sometimes with garnet). However, these enclaves are extraordinarily scarce and small (generally less than 5 cm). Very rarely some biotite granodiorite enclaves may also be found.

Leucogranites normally show very sharp and flat contacts, which may cut the banding and schlieren of tonalites obliquely. Nevertheless, neither nematic stoping (as may be seen further to the north in the Costa Brava; EMRIQUE, 1981) nor tonalite xenoliths have ever been observed.

On the other hand, leucogranites seem to be later than granodiorites, since these are crossed by some leucogranitic dykes and, in addition, they may contain granodiorite enclaves, as mentioned previously, although the granodiorite-leucogranite contacts do not seem to be sharp. Furthermore, leucogranites have often been seen situated on top of the granodiorites (more precisely, between granodiorites and tonalites). So leucogranites might represent the apical part in some granodiorite intrusions (VILASELL, 1975; EMRIQUE, 1979, 1981).

Under the microscope the leucogranites show an allotriomorphic microstructure. Or-tho and microcline are abundant and conspicuously perthitic. Plagioclase and generally twinned oligoclase may be zoned, although the zoning is less strong than in tonalites and granodiorites. Biotite is very scarce and displays a tabular or flaky allotriomorphic habit.

**Northern Montnegre**

The Northern Montnegre plutonic group is predominantly of monzogranitic composition. This kind of rock presents very important variations in grain-size but little change in composition.

Granodiorites are also widespread and in addition some diorite, gabbro, and ultramafic stocks are present. All plutonic rocks intrude into Paleozoic rocks (mainly Silurian, Devonian, and Lower Carboniferous, in this area) producing intense contact aureole metamorphism.

9. Ultramafic rocks. A group of very small outcrops of ultramafic rocks exists at the contact with the Silurian-Devonian rocks in Northern Montnegre, near Graviinyà. They are very coarse-grained (1-3 cm) and show cort-
landitic affinities (ENRIQUE, 1983, in press). Amphibole and olivine account for almost the whole rock, but it also contains phlogopite, deep green spinel, and ore minerals in minor amounts. Clinopyroxene is present as an accessory; orthopyroxene has not been observed. Large allotriomorphic amphibole crystals showing brown to colourless pleochroism include poliklinitically many allotriomorphic olivine grains. Following STECKEISEN's (1976) classification, these rocks are olivine hornblendites.

10. Rocks of gabbroid composition. There are several small stocks of basic rocks closely related to the ultramafic rocks just described. They have a simple composition and are formed almost exclusively of a zoned, highly calcic plagioclase (bytownite; see Table 1). They may contain some augite, and generally have no biotite. They are therefore considered as gabbros (HATCH et al., 1972; HUGHES, 1982). These rocks display an ample mineralogical variation from leucocratic (more plagioclasic types) to hornblende-biotite types. Although intense weathering does not allow good observation, the above-mentioned compositional variations may possibly be attributed to gravitational crystal differentiation.

11. Pyroxene-hornblende-biotite diorites ("Can Campo Diorites"). These rocks appear in quite small outcrops. A heterogeneous mixed zone, formed of quartz-diorites to granodiorites, separates the diorites from the neighboring gabbros and hornblendites (ENRIQUE, 1983, in press). The diorites are fine-grained (1-2 mm) and dark grey in colour. They are composed of several minerals: zoned plagioclase, biotite, hornblende, orthopyroxene, augite, and quartz; K-feldspar is very scarce (see Table 2).

12. Porphyritic biotite granodiorites ("Tor德拉 Granodiorites"). A biotite granodiorite bearing rather abundant megacrysts of K-feldspars (up to 2 or 3 cm) outcrops in the most westerly part of the Montnegre Massif around Tordera and Palafolls Castles. Biotite has normally tabular or flaky habit, and is less abundant in these rocks than in the main South Montnegre granodiorites. Quartz is present as allotriomorphic forms and plagioclase form rather intense zoned and hypidiomorphic grains. These rocks contain few dark microgranular enclaves.

13. Muscovite-bearing biotite granodiorites ("Roca Miralles Granodiorites"). South of the porphyritic granodiorites described above and bordering the pelitic to quartzitic Carboniferous materials, a belt of coarse-grained granodiorite outcrops. These rocks have hypidiomorphic K-feldspar, and are relatively rich in biotite. A little muscovite is also present. It is noteworthy that these granodiorites are crossed by many narrow aplitic and pegmatite dykes.

14, 15, 16. Pink leucocratic biotite monzogranites ("Montnegre Granites"). The most northerly part of the Montnegre Massif is formed of a large outcrop of granite-compositional rocks with biotite as mafic mineral. Although they are very different in grain-size from place to place, their chemical composition is very uniform. They generally have pinkish tonalites and contain abundant dark microgranular enclaves in many zones. These enclaves may be fine-grained and quite rich in pinkish biotite, their composition being granodioritic (Table 1, no. 24, and in figures). These enclaves may be very large, sometimes reaching a length of 1 m. They often show a narrow (1-5 cm wide) hybrid zone with medium composition between the enclave and the enclosing granite.

According to the predominant microstructure, these facies granite facies have been mapped: coarse-grained (14), fine-grained (15) and porphyritic (16).

In thin section the microstructure ranges from granular to porphyritic (transition to microgranite). Granular textures are generally allotriomorphic to hypidiomorphic. Mineralogically they are rich in K-feldspar (most of the perthitic orthoclase). Some plagioclases show intense zoning, although they are often weakly zoned.

HYPABYSAL ROCKS

An important dyke swarm of hypabysal rocks crosses the tonalites, granodiorites and leucogranites, mainly in Southern Montnegre. These rocks are mainly of granitic and granodioritic composition. Rocks of tonalitic, dioritic and gabbrodioritic compositions also exist in very subordinate amounts. Neither dolerites nor lamprophyres have been found, although the latter are very prominent in the Costa Brava granites, some km to the north.

The main mapped hypabysal rock types are as follows (see Fig. 2):

17. Biotite porphyritic microgranites;
18. Biotite porphyritic microgranodiorites;
19. Hornblende-biotite porphyritic microtonalites;
20. Hornblende-biotite porphyritic microdiorites;

Porphyritic microgranites and microgranodiorites are the most important dykes, not only in number but also in width and length. These dykes may reach several km (often 4 or
5), and their width usually attains 20 or 30 m. Their most frequent orientation is NE to ENE, but some may display a NW strike.

In this section the granite, granodiorite and tonalite porphyries show typical porphyritic microstructure. Phenocrysts are normally bipyramidal 5-quartz with magmatic corrosion, strongly zoned plagioclase, idiomorphic biotites, and sometimes K-feldspar and hornblende. The groundmass is microgranular, very fine-grained at the contacts (often black), and somewhat more coarse-grained towards the central part of the dykes.

In Northern Montnegre, and specifically in the pink Montnegre Granite, dykes are very scarce and are generally of leucocratic composition.

**GEOCHEMICAL DATA**

All the major elements were analysed with an atomic absorption spectrophotometer, from fluoboric solution (after FRENCH & ADAMS, 1973). The following international standards were used: NIM-G, GA, G-2, AGV-1, DRN, NIM-N, NIM-P, BM, and NIM-D. Modal compositions of the main rock-types are shown in Table 2 and Figs. 9 and 10.

CIPM norm compositions were obtained after calculations from HUTCHINSON (1974). They have been modified for Fe, using directly $Fe_2O_3$ corrected by the Oxidation Index (ox) after LE MAITRE (1976) (Table 1).

Samples plotted in DE LA ROCHE et al. (1980), DEBON et al. (1982), and AFM diagrams (see Figs. 4-5 and 6-7) show a typical calc-alkaline trend.

PEACOCK's (1931) or alkali-line index is about 62.5 (see Fig. 8); following this classification, these rocks therefore belong to a calcic series.

In the diagram log calc-alkali ratio against silica (BROWN, 1982) (Fig. 8) the Montnegre rocks are plotted above the normal andesite range. This fact, stressed also in the AFM diagram, might, according to BROWN (1982) reveal the lower maturity of these rocks as opposed to that of the andesites mentioned above. Following the same author, this might represent magmatic activity coming from a small evolved magmatic arc overlying a thin continental crust.

The high alkali-line index (over 60) and the distinctive pattern on the AFM diagram are coherent with compressional plutonic rock suites which are believed to be directly related to the subduction process (PETRO et al., 1979).

**CONCLUSIONS**

The plutonic rocks of the Montnegre Massif belong to a composite batholith in which several different intrusions may be recognized.

The rock compositions of the plutons range from acidic leucogranites to ultramafic cortlandites. However, the most widespread types are granodioritic and tonalitic.

Many contacts between different plutons are clearly sharp and at least some leucogranite plutons post-date the tonalites and granodiorites.

A prominent dyke swarm cuts all the plutonic rocks, mainly in the southern zone. The dyke-rock composition ranges from intermediate porphyritic microdiorites to porphyritic microleucogranites and felsites, although the most abundant types are of granitic composition.

All the igneous rocks show a typical calc-alkaline trend and have a calcic character according to PEACOCK's (1931) classification.

The Montnegre plutonic series shows a similar trend to the recent calc-alkaline volcanic series of intermediate maturity.

The trend in the AFM diagram and the high alkali-line index are consistent with compressional rock suites related to subduction processes.

The existence of andesitic to rhyolitic volcanism in the Pyrenees not far from the studied plutonic and hypabyssal rocks showing similar age and compositions, also suggests a possible subduction zone in this area during the Upper Carboniferous to Lower Permian.

The shallow emplacement of allochthonous plutons and the scarcity of andesite zones and autochthonous granitoids also suggests a deep crustal or infra-crustal origin.

If the above considerations are correct, RIDING's (1974) proposed model of the Hercynian Orogenic Belt to the east of the North Iberian microplate could be compatible with the preliminary results obtained in the Catalan Coastal Ranges in the Montnegre area.

Nevertheless, the above considerations cannot be taken as definite, as they are at present drawn from a petrographical study and preliminary research into major geochemical elements. Further research is yet to be carried out on trace elements and isotopes to enable a fuller conclusion to be reached.

**ACKNOWLEDGEMENTS**

The mapping of the Montnegre Massif to 1:25,000 scale was supported by the Servei Geològic de la Generalitat de Catalunya.

**REFERENCES**


