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STRUCTURAL STATE OF K-FELDSPAR IN SOME HERCYNIAN GRANITES FROM IBERIA: A REVIEW OF DATA AND CONTROLLING FACTORS

LUIS J.P.F. NEVES[1] AND MANUEL M. GODINHO[1]

Departamento de Ciências da Terra, Universidade de Coimbra, 3049 Coimbra codex, Portugal

Abstract

Several hundred concentrates of K-feldspar from Hercynian granites of central Portugal (western Iberian Massif) and associated pegmatites and aplites were studied using X-ray powder-diffraction methods, in order to assess their structural state and make inferences concerning petrogenesis. Indicators of structural state include the diffraction pattern in the 2θ region 29–31°, obliquity, the ordering index Δ_{SM} and Al–Si distribution derived from unit-cell parameters. In about 96% of the concentrates from granites, the structural state of K-feldspar assumes a range of values, instead of a single end-member value of fully ordered or disordered state; pegmatites and aplites show less variability in structural state than the associated granites. In the great majority of samples from granites, more than 84% of Al is accumulated in the *T*1 site of the K-feldspar. The dataset as a whole, along with some case studies, indicate that the cooling rate of the plutons was a determining factor in controlling the ordering process of K-feldspar; rapid unroofing of the "older" granites enhanced the cooling rate, thus retarding ordering.

Keywords: K-feldspar, structural state, granites, thermal history, Iberian Massif, Portugal.

Sommaire

Nous avons étudié plusieurs centaines de concentrés de feldspath potassique provenant de granites hercyniens de la partie centrale du Portugal (massif ibérique occidental) et du cortège de pegmatites et d'aplites associés par diffraction X (méthode des poudres) afin d'en déterminer le degré d'ordre et d'en tirer des indices pétrogénétiques. Comme indicateurs du degré d'ordre, nous avons étudié l'intervalle de 29–31° 2θ, l'obliquité, l'indice Δ_{SM} et la distribution Al–Si telle que dérivée des paramètres réticulaires. Dans environ 96% des concentrés provenant de granites, le degré d'ordre s'étale sur un intervalle de valeurs, plutôt qu'une valeur unique, soit du pôle ordonné, soit du pôle désordonné. Dans les pegmatites et les aplites, le feldspath potassique montre moins de variabilité en degré d'ordre que dans les granites associés. Dans la grande majorité d'échantillons provenant de granites, plus de 84% de l'aluminium est accumulé dans les sites *T*1. Les données en général, ainsi que certains exemples-types, font penser que le taux de refroidissement d'un pluton était le facteur déterminant dans la mise en ordre du feldspath potassique. La dénudation rapide de granites précoces a accéléré le taux de refroidissement, et a ainsi retardé la mise en ordre.

(Traduit par la Rédaction)

Mots-clés: feldspath potassique, degré d'ordre, granites, évolution thermique, massif ibérique, Portugal.

Introduction

The structural state of K-feldspar commonly is used as a petrogenetic indicator in granite studies. In fact, as it is controlled by several physical and chemical factors (*e.g.*, Martin 1974), the most important being thermal history, fluid availability and deformation (Smith 1974, Parsons 1977), some petrogenetic constraints can be proposed if the structural state of a K-feldspar in a rock is known.

A number of Hercynian granite plutons from central Portugal have been studied in order to ascertain the structural state of the K-feldspar, and subsequently to make inferences concerning the physical conditions that prevailed during pluton evolution. Several hundred samples have been studied since the 1970s, and these data has been published in the Portuguese geological literature. A review of data, as well as the arguments in favor of cooling as a dominant factor in controlling the degree of order of K-feldspar in these granites, will be presented in this paper. As the data were published in articles by at least one of the present authors, a consistent description of methods will be also presented in order that quality of the data can be ascertained.

[1] *E-mail addresses*: lneves@ci.uc.pt, mgodinho@ci.uc.pt

Geological Setting

The largest exposure of granitic rocks of the Hercynian orogen in Europe occurs in the Iberian Massif, which includes most of the Portuguese territory. As a consequence, granitic rocks are dominant in large areas of central and northern Portugal (Fig. 1). Magmatism in the Iberian Massif was most concentrated between *ca.* 280 and *ca.* 320 Ma ago, as shown in the compilation of radiometric data on the Hesperian Massif by Pinto *et al.* (1987), who noted only a minor proportion of Hercynian granites older than 320 Ma (up to 380 Ma). On the basis of field relations, mineralogy, age and depth of emplacement, Hercynian granites were conveniently subdivided into two suites, "older" and "younger" granites (*e.g.*, Schermerhorn 1956, Oen 1958). The age of these suites was constrained by Rb–Sr data by Priem *et al.* (1970), who provided mean ages of 309 ± 11 and 290 ± 11 Ma for the "older" and "younger" rocks, respectively.

Dozens of plutons of the "older" suite have been mapped; they consist essentially of syn- to late-tectonic muscovite and muscovite–biotite granites, occurring as semiconcordant mesozonal plutons in anticlinal structures developed in metasedimentary rocks of Late Precambrian – Cambrian age. These granites range from fine to medium grained and from equigranular to porphyritic, and show a fairly evolved geochemistry, with enrichment in SiO_2, Li, Rb and Sn (72.5%, 240 ppm, 380 ppm and 60 ppm on average, respectively). The plagioclase is usually albite, and in some cases low-Ca oligoclase. Geochemical and isotopic evidence points to an origin for the granites by partial melting of metasedimentary rocks (Reavy *et al.* 1991, Neves 1991a, 1993, Beetsma 1995) as a result of crustal thickening induced by continental collision. Thermobarometric data suggest emplacement of these magmas at levels of 12–15 km in the crust (Godinho 1974, Neves 1995). Primary muscovite is an important modal constituent of this suite, accounting for 8 to 12% of the volume of the rock, whereas biotite usually accounts for only 2–4%. This fact, as well as the occurrence of associated pegmatites and aplites, suggest that H_2O was relatively abundant in the parental magmas, specially during the terminal stages of crystallization.

The "younger" suite consists of late- to post-tectonic mesozonal to epizonal plutons, mainly composed of undeformed coarse-grained porphyritic biotite and biotite–muscovite granites, showing discordant relationships with metasedimentary rocks and "older" plutons. Those granites are less evolved geochemically than the "older" granites; in fact, they contain on average 70.0% SiO_2, 90 ppm Li, 275 ppm Rb and 12 ppm Sn. The plagioclase is usually oligoclase, but occasionally andesine. The oxygen isotope signature of these granites points to an origin of the magma by partial melting of a heterogeneous portion of the lower crust (Neves 1993, Beetsma 1995). Thermobarometric data suggest emplacement at 6–8 km in the crust (Neves 1995). Biotite is the dominant mica (9–12%); muscovite is secondary in nature and in amount (1–5%). Associated pegmatites and aplites are less common than in the case of the "older" suite. On the basis of geological evidence, it is possible to infer that saturation in H_2O was not achieved as early in the late stages of magmatic crystallization as in the younger suite.

K-feldspar accounts for 15 to 25% of granites, regardless of its age and tectonic setting. It is usually perthitic, dominantly anhedral and strongly poikilitic; thus, textural features indicate late-stage growth. K-feldspar crystals range from *ca.* 0.1 mm to 1 cm across; in the porphyritic "younger" granites, K-feldspar megacrysts are centimeter-sized, euhedral in shape and also of a strongly poikilitic nature. K-feldspar is slightly to moderately (although locally strongly) deformed in "older" granites, whereas in "younger" granites, it is undeformed or slightly deformed. The composition of the potassic phase is usually in the range 88–94% Or, as estimated by X-ray-diffraction methods (Godinho 1980, Neves 1985, 1991b).

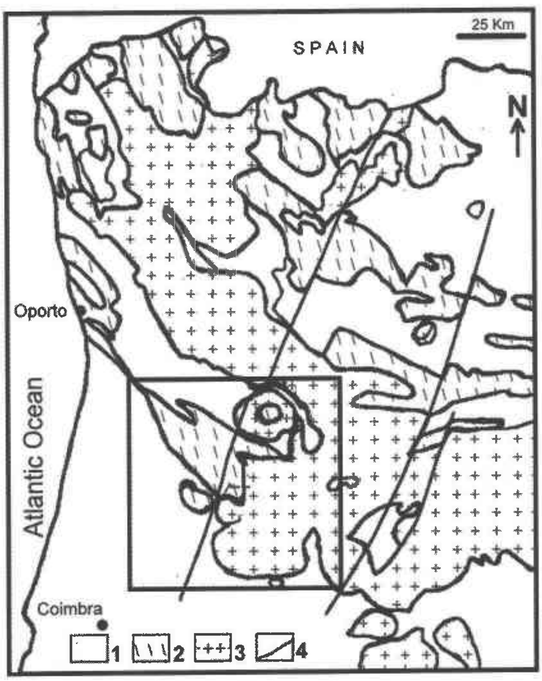


Fig. 1. Simplified geological map of northern and central Portugal. Only the "older" and "younger" Hercynian granite suites are represented (symbols 2 and 3, respectively); other rocks are shown in white (1), and faults, as dark lines (4). The sampled plutons are located inside the square.

Experimental Methods

Most samples of K-feldspar were studied as concentrates obtained from unweathered (or virtually unweathered) representative samples weighting from 1 to 5 kg according to grain size of the rock; in the case of some pegmatites, only one large crystal (0.05 to 0.50 kg) was studied. As the K-feldspar of the granites is usually perthitic, samples were crushed to a grain size not larger than 150 μm. K-feldspar was concentrated through the combined use of conventional magnetic and heavy-liquid procedures; in the latter, tetrabromoethane diluted with acetone was used. The purity of the concentrates was checked by optical observation of the grains after they had been stained with a saturated sodium cobaltinitrite solution; the proportion of K-feldspar grains was at least 96% in the final concentrates.

The structural state was assessed by X-ray powder-diffraction methods, using Philips equipment with Cu$K\alpha$ radiation. For the measurement of absolute values of the diffraction angles, instead of angular differences, annealed potassium bromate was added to each sample as an internal standard, and its (101) and (202) peaks used to provide correction of feldspar reflections [the accepted value of the bromate $2\theta(101)$ peak is 20.223°].

Most of the diffractograms were manually interpreted; 2θ angles or angular differences considered are the average of at least three diffractograms of each sample. The diffractograms were obtained at a speed of 0.5°/minute, and their peaks read at a distance from the background that was 0.6 to 0.9 of their total peak height.

Recent data were collected with an automatic system, in which peak measurements were obtained with software provided by the manufacturer (PC–APD). The position of each recognized peak was carefully controlled, and adjustments made where necessary. The readings used are the average of two diffractograms obtained for each sample.

Estimation of Degree of Al–Si Order

The structural state indicators used in this paper are as follows:

1) A qualitative assessment of the variability in structural state was carried out by a comparison of the X-ray pattern obtained in the (angular) region 29–31° (131 and $1\bar{3}1$ peaks) with a scale of nine standard patterns, as represented in Figure 2, each pattern of this scale being symbolized by a letter from A to I. Thus, it may be considered that a qualitative variable D_t may assume values from A to I. Where D_t is equal to A, the K-feldspar is exclusively of monoclinic symmetry; where D_t is equal to I, the K-feldspar is exclusively triclinic; intermediate values of D_t mean that the feldspar is a mixture of the two symmetries. Obliquity (Δ) was measured by the method proposed by Goldsmith & Laves (1954) where D_t = I; where D_t = B, … H; the method proposed by Dietrich (1962) was used in order to obtain the highest value of Δ for the sample. Measurement error is less than 5% (at the 0.95 probability level) in all cases.

2) An ordering index (Δ_{Sm}), as defined by Godinho & Jaleco (1973), was estimated. This index is based on the angular difference $\Delta 2\theta = 2\theta(\bar{2}04 - 2\theta(060)$, whose value is a minimum for completely ordered feldspars and maximum for completely disordered ones. Assuming that the angular difference changes linearly with degree of order, and accepting the X-ray information on the possible end-member state for K-rich feldspars (Or > 50%) of Orville (1967), Δ_{Sm} was defined by Godinho & Jaleco (1973) in order to provide a result ranging from 0 (high sanidine) to 1 (maximum microcline). New X-ray data on end-member feldspars were presented by Kroll & Ribbe (1987), which led to a

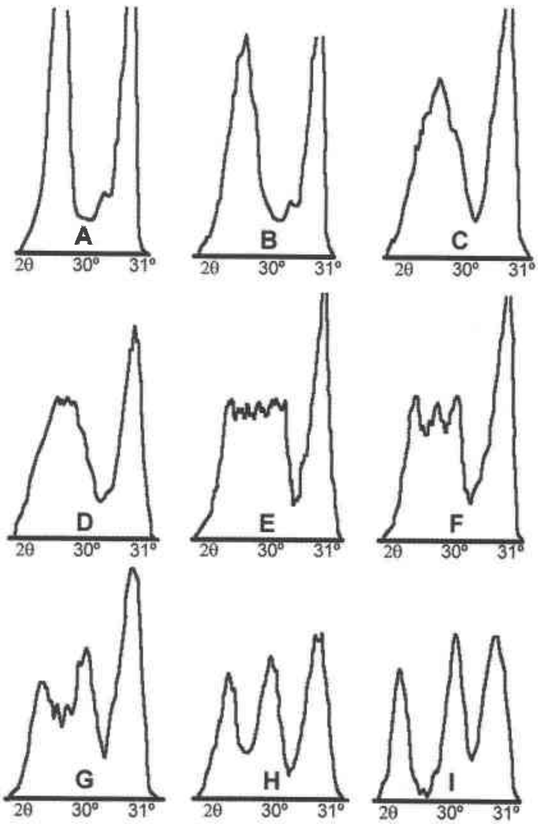


FIG. 2. Scale of reference X-ray-diffraction patterns of natural samples of K-feldspar used for comparison with observed patterns (after Godinho & Jaleco 1973). Limiting terms A and I correspond to single-phase monoclinic and single-phase triclinic symmetry, respectively; other patterns correspond to monoclinic + triclinic and triclinic + triclinic symmetries that coexist.

reassessment of this indicator (Neves & Godinho 1995). In the new formulation, it is defined as:

$$\Delta_{SM} = 15.32 - (\Delta 2\theta) / 0.608 \quad (1)$$

The results are still expressed in the same range (0 to 1). All past data used in this paper were recalculated with this new formula. Considering that the total Al content of the $T1$ sites [ΣAl(T_1)] is 55% in high sanidine and 100% in maximum microcline (Kroll & Ribbe 1987), and assuming a linear variation of $\Delta 2\theta$ with degree of order, Neves & Godinho (1995) proposed the following theoretical relation:

$$\Sigma \mathrm{Al}(T_1) = 45\ \Delta_{SM} + 55, \quad (2)$$

which is equivalent to

$$\Sigma \mathrm{Al}(T_1) = 744.40 - 74.01\ \Delta 2\theta \quad (3)$$

Indeed, rapid estimates of ΣAl(T_1) through the use of (2) or (3) correlate well with ΣAl(T_1) determined from cell parameters. Using information available for 116 samples of K-feldspar of Portuguese granites (78 monoclinic and 38 triclinic), a Pearson correlation coefficient of 0.92 (significant at the 0.95 probability level) was obtained between rapid and accurate estimates (Neves & Godinho 1995).

3) Unit-cell parameters were determined with the program of Appleman & Evans (1973); more recently, a microcomputer version of this program by Benoit (1987) was used. At least 10 diffraction peaks for monoclinic and 12 for triclinic feldspars were used in the calculations. The Al–Si distribution was subsequently determined with the formulae provided by Kroll & Ribbe (1987), and ΣAl in the T_1 sites [ΣAl($T1$)] was calculated; the result is considered the most accurate estimation of ΣAl($T1$).

THE DATA

The data discussed here were collected from the literature wherever enough information on materials and methods was available; papers by Godinho & Jaleco (1973, 1975), Godinho (1980, 1982) and Neves (1985, 1991b, 1996) were selected, which represent more than 90% of published data. Some unpublished data by the authors, collected using methods previously described, are also considered in this review.

Diffraction patterns in the 2θ region 29–31° and obliquity

Information on the structural state indicator D_t is available for 450 K-feldspar samples; it is presented in histogram form (Fig. 3).

A and I values of D_t are scarce in the granites being studied (4% of all samples), and relatively infrequent in pegmatites and aplites (*ca.* one-third of the respective samples). The two suites of granites are not significantly different where the D_t value is concerned, and only a few samples are exclusively monoclinic or triclinic. An interesting feature is the high number of K-feldspar samples that have no dominant symmetry and are mixtures (E and F types). This is the case with 25% of the

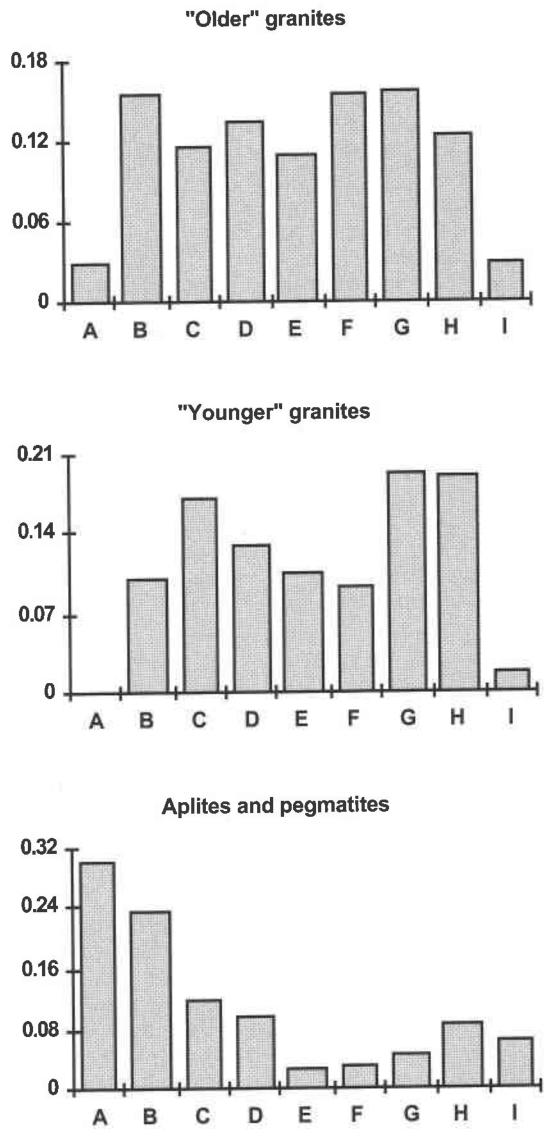


FIG. 3. Histogram of relative frequencies of the standard X-ray-diffraction patterns (as defined in Fig. 2) for the K-feldspar of the "older" and "younger" granitic suites, and associated pegmatites and aplites. The number of samples is 271, 85 and 94, respectively.

K-feldspar samples from the "older" granites, and 20% of the samples from the "younger" ones. These observations imply that, in about 96% of the granite samples, the structural state assumes a range of values instead of a single value. As a rule, monoclinic and triclinic (or more than one triclinic) symmetries coexist in variable proportions within the same sample in the granites being studied. On the other hand, pegmatites and aplites are more likely to be almost exclusively monoclinic or triclinic, showing a lower variability in structural state than the associated granites.

A similar conclusion may be drawn from the histograms of the 258 highest-obliquity values presented in Figure 4; 88% of the samples from the two granitic suites have intermediate obliquity values, and in only 8% of them is obliquity above 0.90. In pegmatites and aplites associated with granites, obliquity never exceeds 0.80; 44% of the samples show values of less than 0.10, never exceeding 0.80. Observations by other authors on obliquity variability compare with the present data (*e.g.*, Dietrich 1962). The distribution of values in Figure 4 also suggests that obliquity tends to be higher in the "younger" than in the "older" suite; on average, obliquity is lower in pegmatites and aplites than in the associated granites.

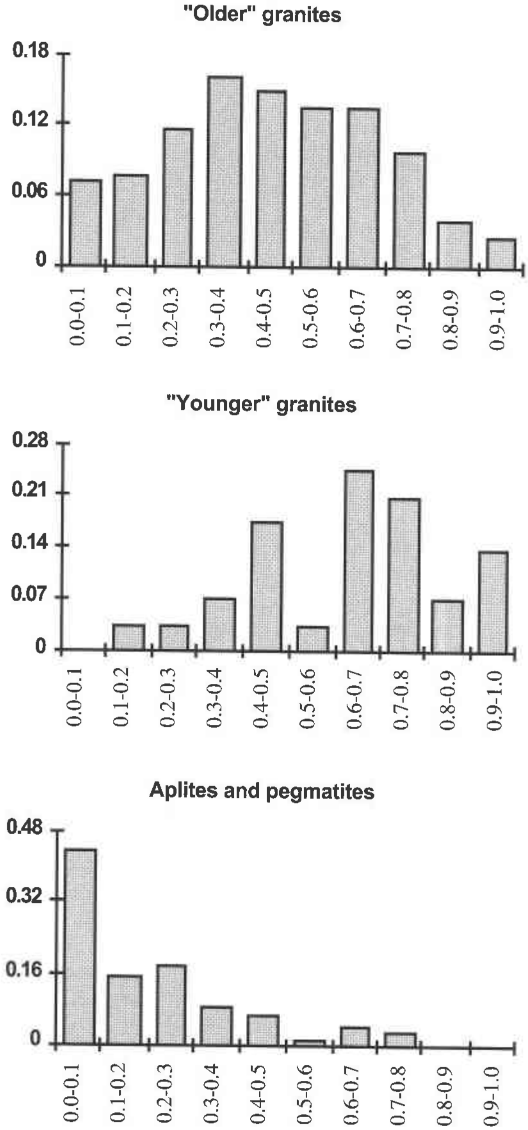


FIG. 4. Histogram of relative frequencies of the maximum obliquity of the K-feldspar for the two granitic suites and associated associated pegmatites and aplites. The number of samples is 156, 29 and 73, respectively.

The Δ_{SM} index of order and $\Sigma Al(T_1)$ values

Histograms of 333 observed Δ_{SM} values are presented in Figure 5; since most of the samples are a mixture of structural states, the corresponding Δ_{SM} values must be considered as averages. The shape of the histograms for "older" and "younger" granites is not very different from a gaussian distribution; this fact may be interpreted as a result of the application of the central limit theorem to a distribution of values that are mostly averages. A Kolmogorov–Smirnov test shows that value sets of "older" and "younger" granites are not significantly different at the 0.95 probability level; on the whole, 86% of the granite samples have Δ_{SM} greater than 0.65, which means that for the majority of the K-feldspar, more than 84% of Al is accumulated in the $T1$ structural sites. The K-feldspar of pegmatites and aplites is considerably less ordered; in fact, only 57% of the samples have Δ_{SM} higher than 0.65. The average Δ_{SM} value observed for granites is 0.79, and for pegmatites and aplites it is 0.68.

Approximately the same behavior is observed when the degree of order of the K-feldspar is evaluated from unit-cell parameters. A summary of data on $\Sigma Al(T_1)$ estimated from unit-cell parameters for K-feldspar from 119 granites and 38 pegmatites and aplites is presented in Figure 6. As stated, the results are in good agreement with estimates based on the rapid method. For example, the estimated average Al content in $T1$ sites of the 157 samples represented in Figure 6 is 87.0%, whereas an average of 88.7% is obtained through the application of equation (2) to the weighted average of the Δ_{SM} value for all 333 measured samples (which is 0.75).

K-feldspar from granitic rocks was grouped independently of origin, and separated Δ_{SM} histograms produced for dominantly monoclinic (A-, B-, C- and D-type), mixed disordered structures (E- and F-type) and dominantly triclinic feldspars (G-, H- and I-type); the results are presented in Figure 7. Samples of monoclinic

K-feldspar show a range of Δ_{SM} from 0.52 to 0.87, with an average value of 0.68; feldspars without a dominant symmetry show a wider range of Δ_{SM}, from 0.58 to 0.88, with an average of 0.77, and triclinic K-feldspars range from a minimum value of 0.73 to a maximum of 0.95, with an average of 0.83. The histograms in Figure 7 show that a considerable degree of overlap occurs between the three types of K-feldspar; this overlap is less

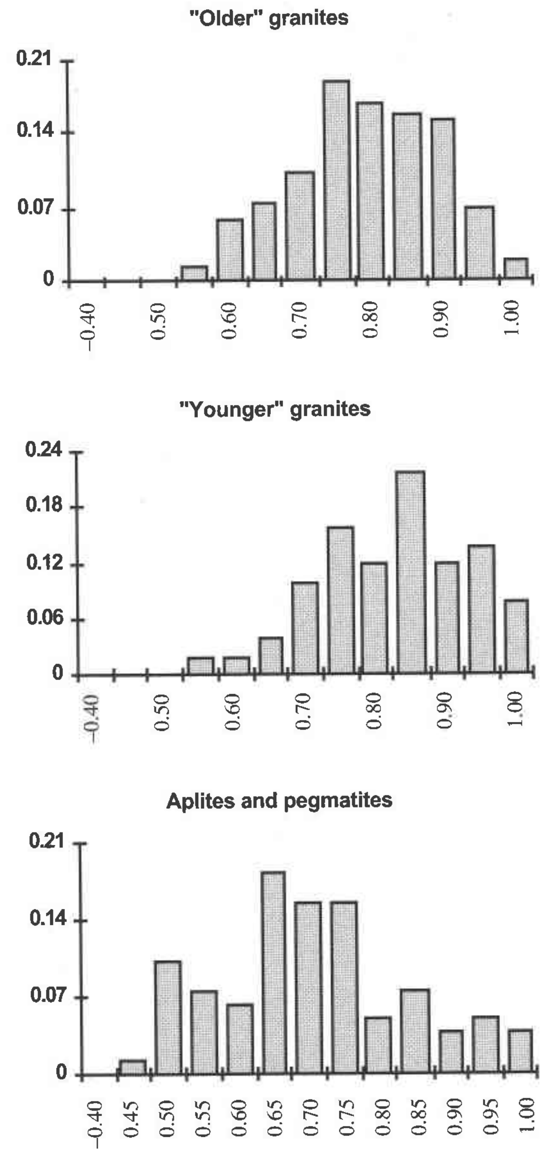


FIG. 5. Histogram of relative frequencies of the Δ_{SM} index of order for the two granitic suites and associated associated pegmatites and aplites. The number of samples is 204, 51 and 78, respectively.

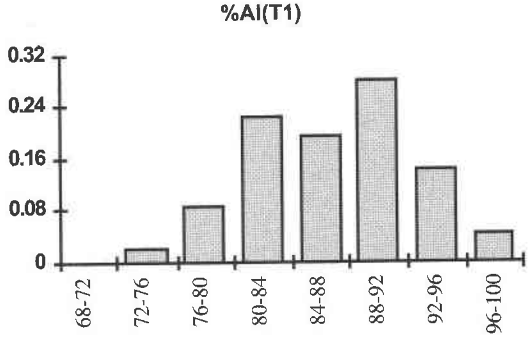


FIG. 6. Histogram of relative frequencies of ΣAl($T1$) estimated from cell parameters for all types of K-feldspar; 157 samples were considered.

important, but still occurs, when monoclinic and triclinic feldspars are directly compared. Thus, information on symmetry only is clearly not sufficient to characterize the degree of order of a K-feldspar; triclinic K-feldspar can apparently be less ordered than monoclinic in some situations.

Cooling rate as the dominant ordering controlling factor

Considering the geological setting, K-feldspar from the "older" two-mica granites would not be expected to have preserved in most cases a monoclinic symmetry, as well as a degree of order comparable with the K-feldspar from the "younger" porphyritic biotite rocks. In fact, several factors are expected to have promoted ordering of the K-feldspar in the two-mica granites: emplacement into deeper levels in the crust, which usually involves conditions of slow cooling, fluid availability during crystallization of the relevant magmas, probably close to saturation conditions, and deformation, which empirically, as well as experimentally, is known to promote both ordering and the monoclinic–triclinic inversion (Bordet & Chauris 1965, Yund & Tullis 1980, Merz *et al.* 1989). Only the peraluminous nature of these granites can partially contribute to retarding the ordering process (Guidotti *et al.* 1973, Martin 1974), but this factor alone does not fully explain the results obtained; in fact, correlation coefficient between Δ_{SM} and whole-rock A/CNK$_{mol}$, available for 45 samples of two-mica granites, is not significant at the 0.95 probability level. In addition, no correlation between the degree of order of K-feldspar and the grain size of the rocks was detected.

An explanation of our findings could be related to the cooling history of these rocks. Recent papers suggest a high rate of denudation in the region at the time of emplacement of the "older" granites, based on gechronological, thermobarometric and fission-track studies (Godinho *et al.* 1997, Pereira *et al.* 1998); this rate has probably exceeded 1 mm/yr for a short time and could have been even higher. The removal of a large portion of the metamorphic and sedimentary cover carried the two-mica granites to shallower levels in the crust, allowing for a relatively fast cooling of the rocks

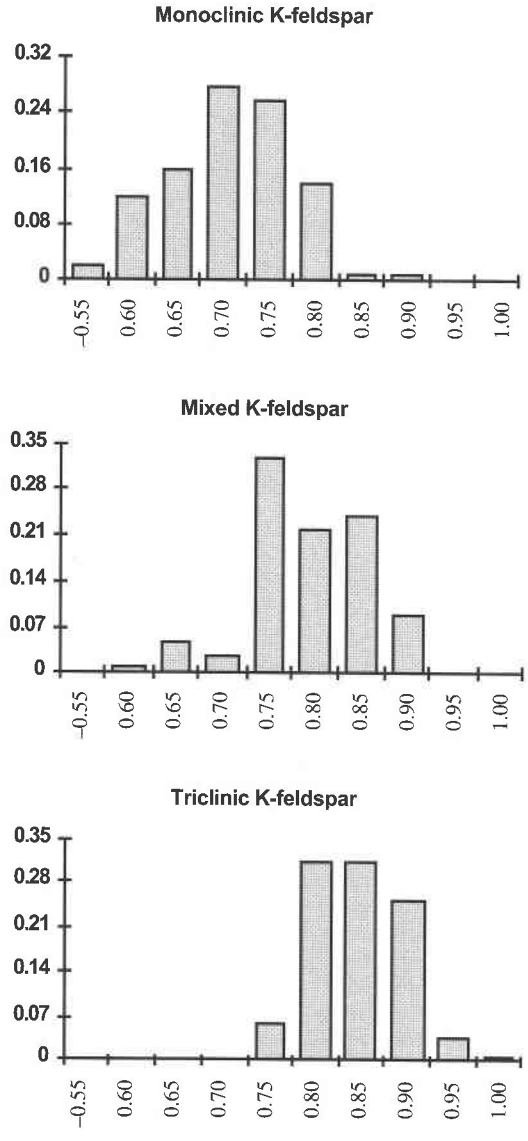


FIG. 7. Histogram of relative frequencies of the Δ_{SM} index of order for the A–B–C–D (dominantly monoclinic), E–F (mixed) and G–H–I (dominantly triclinic) groups of X-ray-diffraction patterns of K-feldspar; 77, 54 and 55 samples, respectively.

to a temperature under 400°C, thus preventing both ordering and the monoclinic–triclinic inversion to proceed. In fact, tweed-textured orthoclase consists of micro-domains with different senses of order; the development of an overall triclinic symmetry implies the reversal of the orientation of adjacent domains, which is only possible under conditions of slow cooling, or with the help of external factors, such as fluid activity or deformation (Brown & Parsons 1989).

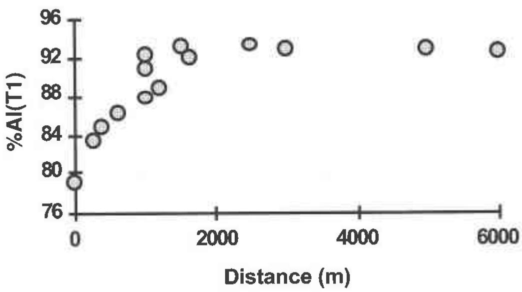
In conclusion, thermal history is probably the most important factor in controlling the ordering of K-feldspar from the two-mica granites; this factor was more effective in retarding ordering than others (*e.g.*, fluid availability, tectonic stress) were in promoting it.

The results obtained for the porphyritic biotite granites are not unexpected. Although they intruded at a time when denudation rate had greatly decreased (0.05 to 0.11 mm/yr, *cf.* Godinho *et al.* 1997, Pereira *et al.* 1998), they where emplaced at shallower levels in the crust than the two-mica granites; thus cooling was relatively fast, which generally prevented the symmetry inversion and retarded ordering.

Aplites and most of the pegmatite bodies that were studied were intruded as small late-stage veins in both granitic suites, at a time where the host granites were below their solidus temperature. A relatively rapid cooling rate is likely in these conditions. This environment can account for the presence of less ordered structures in the K-feldspar of most of these rocks.

Our proposal of cooling rate as a determining factor in Al–Si ordering also explains some spatial differences observed in the degree of order of the K-feldspar of some plutons. In the case of the Tábua pluton, a porphyritic biotite granite that outcrops over an area of a few hundred km^2, it was found that Al–Si order is fairly constant over the whole pluton [$\Sigma Al(T_1)$ = *ca.* 92%], with the exception of a 2-km band along the external margin (Fig. 8). A good correlation was obtained between the distance from the contact and $\Sigma Al(T_1)$ for these 2 km; $\Sigma Al(T_1)$ decreases from *ca.* 92% to *ca.* 78% at the contact with the metasedimentary country-rock (Neves *et al.* 1996). Cooling rate of this pluton was predicted over the interval 650–500°C through a numerical model developed by Pereira *et al.* (1996); it also correlates well with the observed Al–Si order of K-feldspar (Fig. 8). A similar pattern was obtained for the Avô pluton, a small body of two-mica granite that occurs in central Portugal (*cf.* Neves 1996), and also for the Sintra pluton, an Alpine composite body outcropping near Lisbon (*cf.* Neves & Godinho 1990); owing to the smaller size of these plutons, internal variations in the degree of order of the K-feldspar is limited to a few hundred meters from the contact.

Where cooling has essentially been accomplished by conduction and no subsequent thermal disturbances have occurred, K-feldspar will preserve a lower degree of Al–Si order in a band of variable width along the external margin of the pluton. This pattern can be easily



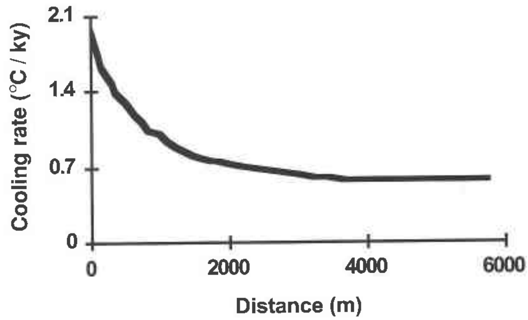


FIG. 8. Predicted rate of cooling of a "younger" granite pluton (the Tábua pluton) and ΣAl($T1$) of its K-feldspar, both plotted against distance from the contact with the country-rock metasediments. Cooling rate refers to the temperature range 650–500°C (after Neves *et al.* 1996).

identified if sampling is spatially distributed in an adequate way. On the other hand, where convection was the dominant mechanism of cooling, the degree of Al–Si order of the K-feldspar is expected to be fairly uniform through the pluton, as a result of a relatively homogeneous rate of cooling.

Wherever granites of different ages are in contact, the structural state of K-feldspar can also reflect heat-transfer phenomena. In the Viseu region of central Portugal, "older" two-mica granites are in contact with a large pluton of "younger" porphyritic biotite granite. A cross-section on the Salgueiral granite, an "older" pluton, shows that the degree of order of the K-feldspar decreases from an average value of ΣAl(T_1) = *ca.* 94% to less than 75% close to the contact with the porphyritic biotite granite (Fig. 9). Metamorphic andalusite and sillimanite were formed in the two-mica granite, at maximum distances of 700 and 200 meters from the contact, respectively. Thus, high temperatures were reached in the contact aureole (well above 400°C, and at least 600°C close to the contact), which allowed the K-feldspar to become less ordered. These less ordered structures were preserved as a consequence of a relatively fast cooling to *ca.* 300°C, which is the equilibrium temperature corresponding to the level of emplacement of the porphyritic biotite granite in the crust (Pereira *et al.* 1996).

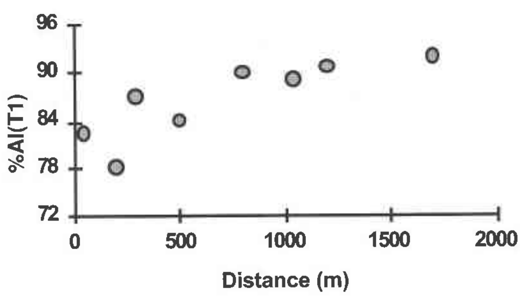


FIG. 9. ΣAl($T1$) of the K-feldspar of a two-mica Salgueiral granitic pluton plotted against distance from the contact with the porphyritic biotite granite pluton of Viseu. ΣAl($T1$) is approximately constant for distances greater than *ca.* 2 km (after Neves & Stephens 1997).

CONCLUSIONS

Data on indicators of structural state of K-feldspar from the "older" and the "younger" Hercynian granites suites and associated pegmatites and aplites in central Portugal point to the following conclusions:

1) Results obtained through rapid methods of evaluation of structural state correlate well with more accurate and time-consuming methods based on unit-cell parameters.

2) Indicators are quite variable in each suite and even in each pluton; this variability is lower in pegmatites and aplites than in the associated granites.

3) In most samples, a dominant symmetry is not identifiable, and exclusively monoclinic or triclinic symmetries are scarce. Information on symmetry only is not sufficient to characterize the degree of Al–Si order; although, as a rule, triclinic feldspar is more ordered, it can also be less well ordered than monoclinic samples.

4) In most granite samples, more than 84% of the Al accumulates in T_1 structural sites, with no significant difference between the two suites. Obliquity tends to be higher in "younger" than in "older" granites; on average, pegmatites and aplites have lower obliquity and are less ordered than associated granites.

5) Cooling rate seems to be the dominant factor in controlling the ordering process; a higher degree of order in the interior of plutons studied in relation to their margins can be interpreted as a result of a lower cooling-rate in the interior.

6) Rapid unroofing, inducing a relatively fast cooling-rate, seems to be the most probable explanation for the preservation of monoclinic structures and a moderate Al–Si degree of order in the "older" granites.

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