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THE THERMAL BEHAVIOUR OF SOME FELDSPARS FROM EGYPT

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ABSTRACT

A new and sensitive Hungarian derivatograph is used in studying the thermal behaviour of six feldspars from Egypt and U.S.A., its temperature range is up till 1200 °C. Four endothermic peaks could be noted in the *dta* curves of the studied feldspars. These are: **P1** at 225—330 °C, **P2** at 425—600 °C, **P3** at 695—860 °C and **P4** at 940—980 °C.

The first peak P1 is partly correlated with loss of adsorbed water and partly with loss of constitutional water of certain hydrated silicate minerals like clays present as alteration product of feldspar. This peak can express the extent of alteration of the feldspar. The second peak **P2** is shown to be correlated with the miscibility of the two feldspars forming the perthite or antiperthite under study. Moreover, it is shown to be empirically correlated with temperature of formation. The third and fourth peaks **P3** and **P4** are transition temperatures of plagioclase and microline to the high temperature forms respectively. The last two reaction temperatures are particularly useful as petrogenetic indicators.

INTRODUCTION

The study of the thermal behaviour of feldspars, particularly the alkali feldspars, is of paramount importance. In the first place it gives an idea about the miscibility or homogenization temperature of exsolved perthites and antiperthites. Secondly, phase transitions can be followed and the structural states of feldspars with their temperature changes can be worked out. This turn will help, at least partly, to decipher the crystallization history of the feldspar. A matter which will throw some light on the genesis of the fledspar and hence the enclosing rock whether igneous (like granite or pegmatite) or metamorphic (like gneiss).

Available literature on the subject of thermo-analysis of feldspars are not quite common. Among the contributors are: GOLDSMITH and LAVES 1954 (HEIER 1957), ROSENQVIST 1954 and KOHLER and WIEDEN 1954 (DEER *et al.* 1963). However, recent development in the manufacture of derivatographs has greatly increased the sensitivity of the instrument and made it possible to detect minor thermal reactions and accurately define the temperature of the reaction, besided losses or grains in weight can be estimated. Thus it became essential to reinvestigate the thermal behaviour of feldspars on the light of modern sophisticated equipment.

The present work is an investigation of the thermal behaviour of some feldspars separated from their granites or pegmatite occurring in the basement rocks of the Eastern Desert of Egypt.

Speculation is made concerning the temperature of formation of the enclosing acid rocks.

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TECHNIQUES OF WORK

The used instrument in thermoanalysis is a Hungarian derivatograph with instrumental settings mostly used as follows: weight of sample around 0.5 g, crucible platinum, **TG** 20, **DTA** 1/2, **DTG** 1/5, heating rate 10 °C/min. **HGB** 100, **DGB** 100, spindle 3, stabilization volt 95, temperature range up till 1200 °C, furnace 2. Sometimes duplicate runs are done for each sample. Dry heat treatment is used. It is to be noted that interpretation of the differential thermal analysis curve (*dta*) is aided by both the derivative thermogravimetric (*dtg*) and thermogravimetric (*tg*) curves (KHALIL and EL SOKKARY 1976). The temperature rise curve (*t*) is shown as well together with these three curves.

The feldspars are separated from their corresponding granitic rocks in a high state of purity (above 95 %) by a method which is described in detail by EL SOKKARY (1970). Briefly, the method starts with grinding the rock, the powder is made to pass mesh sieve ranging between 80—100. Slimes are removed and then the powder is subjected to bromoform separation. The light fraction is then subjected to separation by a mixture of bromoform and decalin. Finally the desired feldspar is taken and run through a Frantz Isodynamic separator in order to remove the last traces of ferromagnesian minerals.

Six samples are prepared for thermoanalysis. Five of them with sample numbers (1—5) from the central and southern parts of the Eastern Desert of Egypt, while the last one (sample 6) is from U.S.A. Table 1 lists the analysed samples, their host rocks and localities.

TABLE 1.

Analysed feldspar samples with host rocks and localities.

Sample No.	Host rock	Locality	Separated Feldspar
1	Pink granite	G. Kadabora	Microline microper.
2	Pink porph. granite	Aswan	Microline microper.
3	Amazonite peg.	Um Groof	Amazonite perthite
4	White granite peg.	Hafafit	Microline perthite
5	Garnet peg.	W. Gemal	Oligoclase antiper.
6	---	U.S.A.	Orthoclase crystals

PRESENTATION OF DATA

Table 2 gives the most important reaction temperatures (four in number) of the six feldspars under study beside the total loss in weight of each sample expressed as per cent of sample weight. The first peak **P1** is an endothermic peak that ranges between 225—330 °C and is mostly due to loss of loosely absorbed water.

The second peak **P2** is an endothermioc peak that ranges between 425—600 °C and most probably represents the miscibility or mixing of the two alkali feldspars forming the perthitic or antiperthitic feldspar under study.

The third peak **P3** which is an endothermic peak ranging between 695—860 °C is due to phase transition of the plagioclase feldspar to some high form. The fourth peak **P4** is as well an endothermic peak ranging between 940—980 °C and is due to phase change of microcline to a high form. *Fig. 1* gives the *t*, *dta* and *dtg* curves of one of the analysed feldspars No. 5, while *Fig.* 2 gives the *dta* curves of the six studied feldspars from Egypt and U.S.A.

TABLE 2.

Reaction temperatures in centigrade (°C) of some feldspars from Egypt

Sample No.	P1	P2	P3	P4	Total loss %
1	280	580	860	980	1.09
2	330	560	695	970	0.86
3	250	580	720	955	0.30
4	310	520	825	>825	0.38
5	225	600	805	940	0.75
6	240	425	800	-	0.45

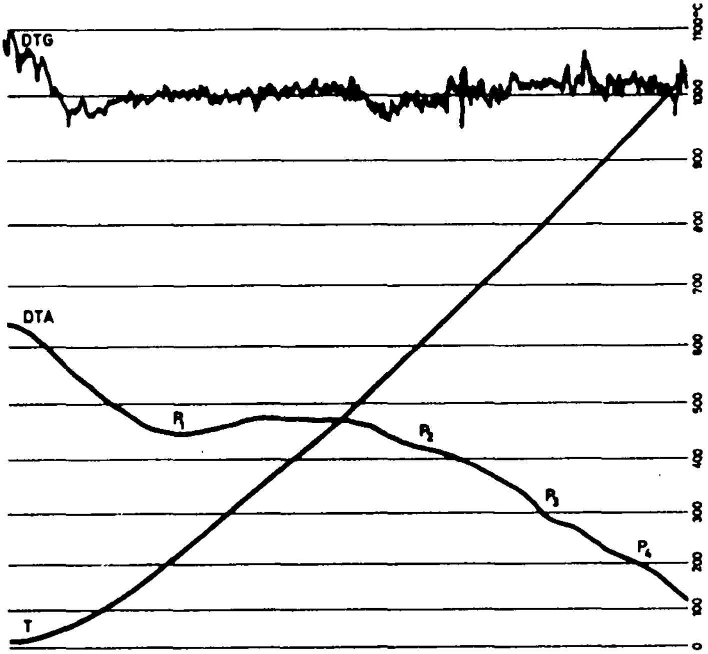

Fig. 1. T, DTA and DTG curves of one of the analysed feldspars, No. 5.

DEER *et al.* (1963) in their rock-forming minerals, the volume on framework silicates mentioned that the *dta* curves for alkali feldspars have generally been reported to show neither endo- nor exothermic peaks, though ROSENQVIST, 1954 noted in some cases a small endothermic peak at about 900 °C which he tentatively intepreted as representing a phase change. KOHLER and WIEDEN 1954 recorded a sharp endothermic peak at 820 °C for an albite from Rischuna, Switzerland.

HEIER (1957) reported that by dry heat treatment of microcline, a number of states with intermediate triclinicities are produced at 1050 °C, and after 720 hours

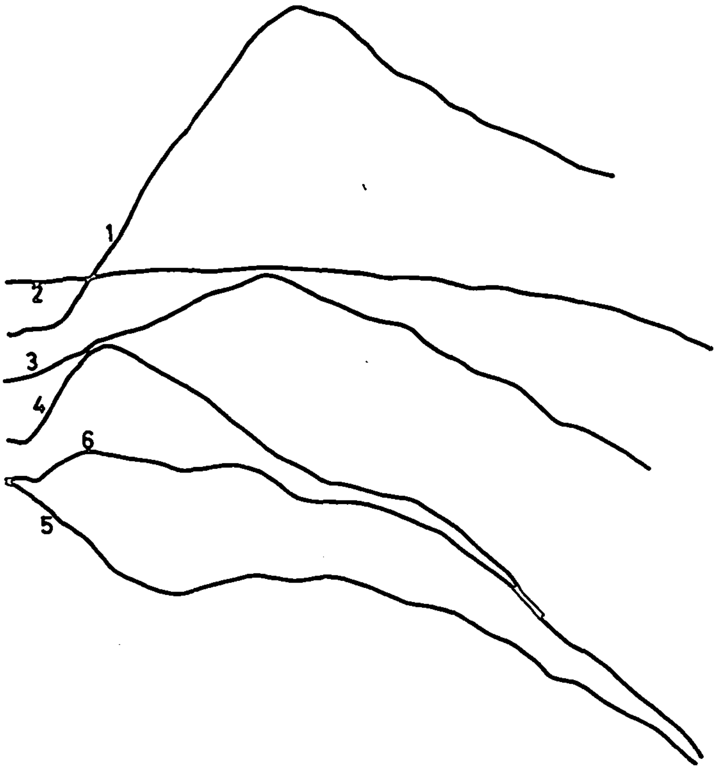

Fig. 2. DTA curves of the six studied feldspars from Egypt and USA.

of exposure at this temperature the monoclinic form is developed, GOLDSMITH and LAVES 1954.

Thus for alkali feldspars whether potassic or sodic some phase change occure between 900—1050 °C and for plagioclases (according to DEER *et al.* 1963) some change occurs at between 780—820 °C correlated with the change to the high temperature form.

THERMAL BEHAVIOUR OF EGYPTIAN FELDSPARS

As already stated in the previous section on presentation of data, four endothermic peaks are noted in the *dta* curves of the studied feldspars from Egypt. The first peak P1 takes the range 225—330 °C and is thought to be due to loss of loosely adsorbed water. As a matter of fact adsorbed water is supposed to be lost at temperature range 100—110 °C. Since the obtained endothermic peak occurs at certainly higher temperature range (225—330 °C), this gives some doubt that this peak is due only to loss of adsorbed water on the feldspars. Tentatively loss of interlayer water or constitutional OH of certain clay minerals or hydrated silicate minerals present as alteration product of feldspars may be postulated.

DEER *et al.* (1972) stated that: The dehydration of halloysite (member of the kaolinite group) proceeds in a number of stages. Some of its adsorbed water (surface and interlayer) is lost on heating to 110 °C as with any other mineral, but the remainder comes off gradually and is not completely expelled until about 400 °C. The same reference (op. cit., p. 262) mentions that *dta* curves of illite show three endothermic peaks, one between 100—200 °C representing loss of loosely held water. Adsorbed water therefore can be driven off at temperatures greater than 110 °C according to the mentioned reference.

Thus the endothermic peak occurring at the temperature range 225—330 °C of the analysed feldspars may be partly due to loss of loosely adsorbed water and partly due to loss of combined water of certain alteration products of the feldspars. The more weathered the feldspar is, the more is its total loss of water as in the case with the feldspar sample No. 1 from Kadabora which gives 1.09 % total loss of weight.

Unmixing or miscibility temperature of the analysed Egyptian feldspars whether perthites or antiperthites range between 425—600 °C as denoted by the endothermic peak P2 on the *dta* curves. Evidence that this peak is correlated with miscibility of the two feldspars forming the perthite or antiperthite under study will be given later. The relation between feldspar composition, miscibility temperature and formation temperature will be dealt with as well in some detail in the next section.

The third endothermic peak that appears on the *dta* curves of the studied feldspars from Egypt ranges between 695—860 °C and is correlated with phase change to some high form of the present plagioclase feldspar whether constituting perthite or antiperthite.

It is to be noted that the analysed perthites and antiperthites behave as if they were mixtures of both potassic feldspar (microcline or orthoclase) and plagioclase feldspar (albite or oligoclase). This can account for the presence of the two endothermic peaks responsible for transition of plagioclase and microcline respectively to the high disordered forms. It seems that grinding the feldspar samples to below 100 mesh sieve size aided in liberating some extent the two feldspars (forming the perthite or antiperthite under investigation) from each other*. Thus the *dta* curve could show the transition temperature of both microcline and plagioclase to the high forms in one and the same curve.

The fourth endothermic peak P4 on the *dta* curves of these feldspars ranges between 940—980 °C, being concerned with the transition of microcline to high forms with intermediate triclinicities.

Consideration of feldspar sample No. 5 which is an oligoclase antiperthite with microcline as the included feldspar does not clearly record the high transition temperature peak P4 on the *dta* curve which is supposed to result from the included microcline, this may be due to its low content in the studied antiperthite. On the other hand feldspar sample No. 6 which is an orthoclase perthite from U.S.A. does not show this high transition peak because itself represents the high disordered form which is monoclinic orthoclase in this particular case.

Thus the present study on the thermal behaviour of some alkali feldspars from Egypt showed the presence of four endothermic peaks at the following temperature ranges: P1 at 225—330 °C, P2 at 425—600 °C P3 at 695—860 °C and P4 at 940—980 °C. This is to be compared with DEER *et al.* (1963) who stated that the *dta* curves for alkali feldspars have generally been reported to show neither endo- nor exothermic peaks.

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* Particularly the pegmatite perthite samples No. 3 and 4 in which the two feldspars forming perthite are visible to the naked eye.

COMPOSITION AND MISCIBILITY TEMPERATURE VS. FORMATION TEMPERATURE

Table 3 gives the composition of four of the studied feldspars expressed in Or, Ab and An weight per cent, besides the same table lists the miscibility temperature of these feldspars as noted from the present *dta* curves and the formation temperature deduced from BARTH diagram relating the composition of the coexisting feldspars to their temperature of formation (DEER *et al.* 1972). The composition of the first three feldspars with sample Nos. 1, 2 and 3 is taken from EL SOKKARY (1970), while the composition of the fourth feldspar with sample No. 4 is also taken from EL SOKKARY (1975).

TABLE 3.

Composition of some studied feldspars in wt. % as related to miscibility temperature (M.T.) and formation temperature (F.T.) in centigrade (°C)

Sample No.	Or	Ab	An	M.T.	F.T.
1	57.5	40.4	2.1	580	680
2	64.2	34.0	1.8	560	600
3	61.5	36.6	1.9	580	620
4	67.8	30.9	1.3	520	580

Fig. 3. is a plot correlating the composition of the coexisting feldspare with their miscibility temperature as directly taken from the *dta* curves. The figure shows that this relation is a linear systematic one i.e. there is proportional systematic relation between the composition of coexiting feldspars and the miscibility temperature noted from peak P2 of the *dta* curves. This assured that the endothermic peak P2 on the *dta* curves of the studied feldspars is due to miscibility of the two feldspars forming the perthite or antiperthite under study.

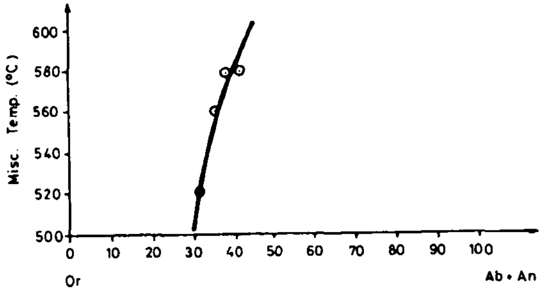

Fig. 3. Miscibility temperature vs. plagioclase content (Ab+An %) in some of the studied feldspars.

Fig. 3. is correlated as well with isobaric equilibrium diagrams for the alkali feldspars in dry melts and at various pressures of water. This figure is to be compared here with *Fig. 4* taken from DEER *et al.* (1972) and represents the isobaric equilibrium relation for alkali feldspars at water pressure=5000 bars. The last curve shows that at a particular feldspar composition (1 Or : 2 Ab), the miscibility temperature becomes nearly the same as the liquifaction temperature at 5000 bars H_2O and equals 695 °C. In this particular case the position of the

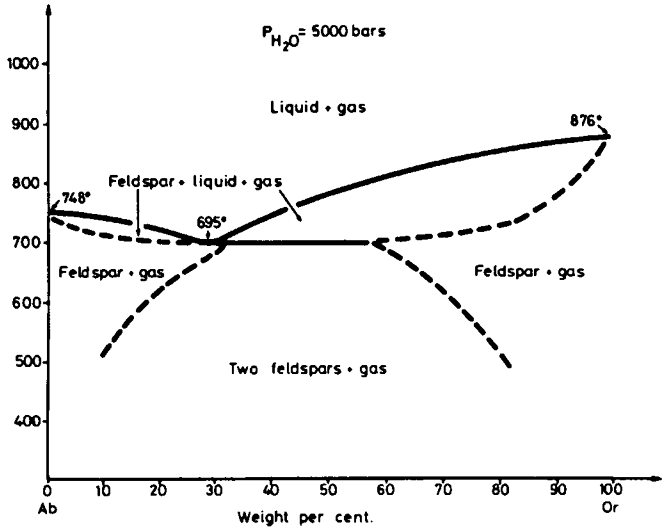

Fig. 4. Composition of feldspar in terms of Or and Ab per cent vs. temperature at 5000 bars H_2O pressure (DEER *et al.* 1972. p. 304).

solvus or unmixing curve directly underlines the solidus and liquidus curves without a gap in between.

Fig. 5. on the other hand gives the relation between formation temperature and miscibility temperature in some Egyptian feldspars. However, this relation is tentative since the curve is drawn with four points only, nevertheless it is promising. Thus the miscibility temperature as taken from the *dta* curve of the analysed feldspar can express its temperature of formation through the binary relation between these two temperatures.

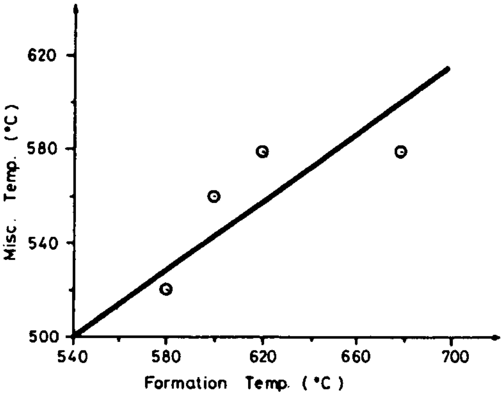

Fig. 5. Miscibility temperature vs. formation temperature in some of the studied feldspars.

DISCUSSION

Four endothermic peaks are noted in the *dta* curves of the analysed feldspar. The first peak P1 occurs at temperature range 225—330 °C. It can be correlated with weatherability or alteration of the feldspar sample i.e. the extent of this peak can be taken as a measure expressing the extent of alteration of the studied feldspar.

The second peak P2 occurring at temperature range 425—600 °C and is presumably due to miscibility of albite in microcline forming perthite or the reverse forming antiperthite. Evidence that this peak is correlated with miscibility of the two feldspars forming perthite or antiperthite under study is given. This evidence stems out from the fact that there is proportional systematic relation between the composition of coexisting feldspars and the miscibility temperature as noted from the *dta* curves. At a certain feldspar composition 1 Or : 2 Ab the miscibility temperature becomes nearly the same as the liquifaction temperature at 5000 bars of H_2O. Moreover, the miscibility temperature as it taken from the *dta* curve of the feldspar can express its formation temperature.

The third endothermic peak P3 ranges between 695—860 °C and represents transition temperature of plagioclase feldspar to the high form. Meanwhile, the fourth endothermic peak P4 ranges between 940—980 °C is concerned with the transition of microcline to high form.

Thus the study of the thermal behaviour of some feldspars from Egypt proved to be useful. This study can throw some light on the extent of weathering or alteration of the studied feldspar. Miscibility temperature of the two feldspars forming perthite or antiperthite is noted as well from the *dta* curves of the analysed feldspars. This miscibility temperature is shown to be correlated with temperature of formation of the feldspar. Transition temperatures of both plagioclase and microcline to the high forms are noted from the *dta* curve of the analysed feldspar which is useful as petrogenetic indicator.

HEIER (1957) could correlate the triclinicity (including low and high forms) of potash feldspars with their temperature of formation. It is already mentioned (EL SOKKARY 1970) that K- feldspars with low triclinicity (high monoclinic form or orthoclase) characterise metasomatic rocks or rocks undergoing chemical change or local redistribution to form porphyroblasts.

Thus the change from low feldspar forms to high ones or the reverse as indicated from the *dta* curves, has its bearing on the genesis of the enclosing rocks of feldspars.

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