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# A CONSIDERATION ON THE RELATION BETWEEN THE ROCK TYPES OF ACID IGNEOUS ROCKS AND THEIR INITIAL Sr ISOTOPIC RATIOS

Hiroo KAGAMI*, Kenji SHUTO** and Masao GORAI**

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## 1. Introduction

The writers have discussed the source materials of acid igneous rocks, based on their initial Sr isotopic ratios (Gorai, 1963; Kagami & Izumi, 1972; Gorai *et al.*, 1972; Kagami *et al.*, 1975). The main point of the most recent paper (Kagami *et al.*, 1975) is as follows.

The plotted data are variously dispersed on the whole-rock isochron diagrams of acid igneous rocks, the degree of dispersion being represented by the value of standard deviation ($\sigma$-value) for initial Sr isotopic ratio (Sr $I$). The dispersion may probably be due to certain geological processes such as admixture of sialic materials, secondary alteration of metamorphism, complicated differentiation process, difference of source materials and so on. Consequently, the Sr $I$ having high $\sigma$-values may not be suitable for the discussion of the source materials of acid igneous rocks.

The writers have examined the source materials of acid igneous rocks, taking notice of the relation between the ages and Sr $I$ having low $\sigma$-values. In such Sr $I$ versus age diagram the points are evidently plotted within a narrow field converging at about $46 \times 10^8$ years ago, which is located just on the presumed Sr evolutional field (trend) of the source materials of oceanic tholeiite. It is noteworthy that these two fields intersect each other at an early stage of the earth's history. It is conceivable that the former field is the Sr evolutional field of the source material for most acid igneous rocks.

Considering from the inclination of the Sr evolutional field above mentioned, the source material of most acid igneous rocks may possibly be a certain basic material, which is similar to the continental tholeiite or basaltic andesite in chemical composition.

On the other hand, the source material of a few acid igneous rocks having very low Sr $I$ may be a certain basic material which resembles the oceanic tholeiite, or a certain ultrabasic material.

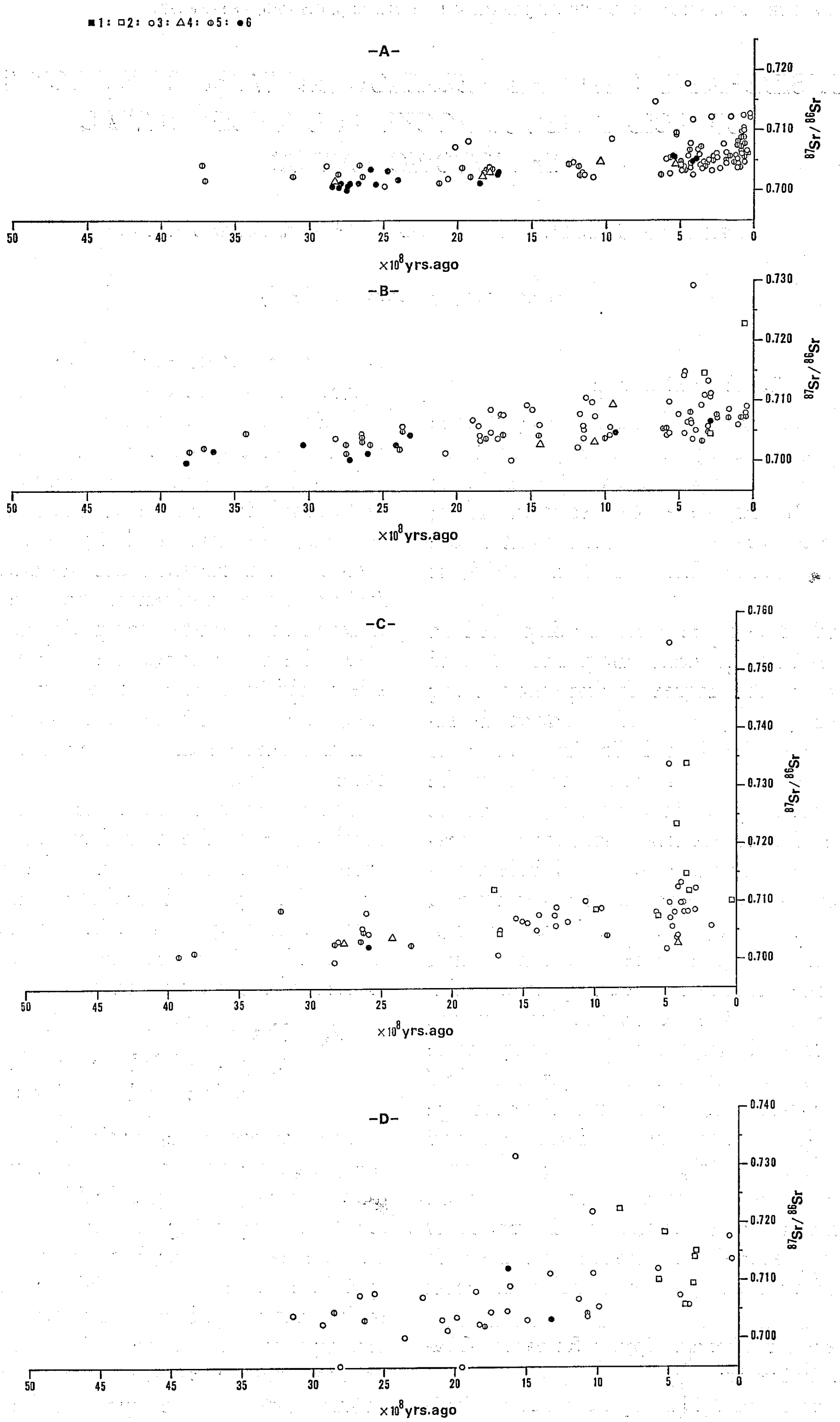
The conclusion above mentioned has been obtained from the consideration of the acid igneous rocks as a whole. The relation between the ages and Sr $I$ for individual rock types of acid igneous rocks has not yet been examined. Therefore the writers would like to discuss the relation in this paper.

## 2. The relation among the rock types, initial Sr isotopic ratios and $\sigma$-values

The writers have recalculated, concerning the acid igneous rocks previously reported in many papers, the ages, Sr $I$ and the $\sigma$-values for Sr $I$ according to the same formula, because each author has his own formula to calculate these values. Taking notice of the rock types of acid igneous rocks, the relations among these values are as follows. The rocks having smaller $\sigma$-values show better interrelation between the ages and the Sr $I$, which is shown in Fig. 1. The rock types of acid igneous rocks are also shown in this figure. As

* Institute for Thermal Spring Research, Okayama University

** Geological and Mineralogical Institute, faculty of Science, Tokyo University of Education, Tokyo


■1: □2: ○3: △4: ⊘5: ●6
-A-
0.720
0.710
0.700
$^{87}Sr/^{86}Sr$
50 45 40 35 30 25 20 15 10 5 0
×10⁸yrs.ago
-B-
0.730
0.720
0.710
0.700
$^{87}Sr/^{86}Sr$
50 45 40 35 30 25 20 15 10 5 0
×10⁸yrs.ago
-C-
0.760
0.750
0.740
0.730
0.720
0.710
0.700
$^{87}Sr/^{86}Sr$
50 45 40 35 30 25 20 15 10 5 0
×10⁸yrs.ago
-D-
0.740
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0.710
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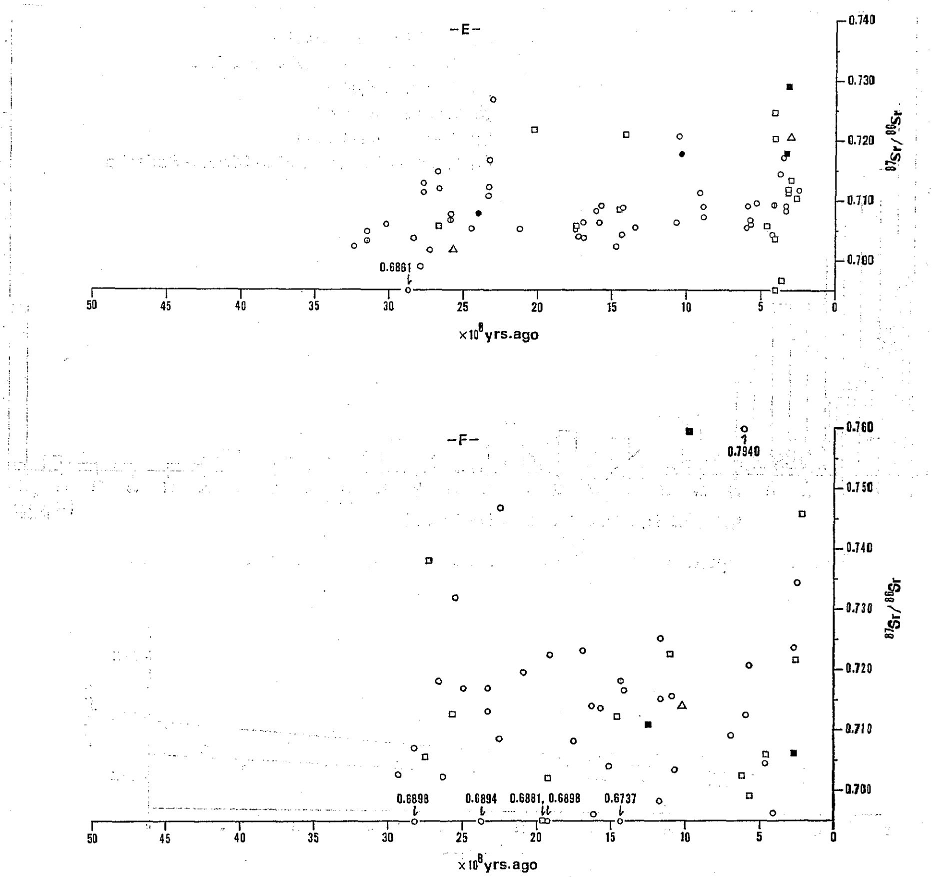


Fig. 1. Relation among the rock types, the ages and initial Sr isotopic ratios classified according to the values of standard deviation ($\sigma$-values, A to F).
1: Alkali feldspar-granite 2: Two mica-granite. Muscovite-granite 3: Granite. Rhyolite 4: Quartz-monzonite 5: Granodiorite. Dacite 6: Tonalite. Quartz-diorite. Diorite. Andesite A: 0.0010 and less B: 0.0011—0.0020 C: 0.0021—0.0030 D: 0.0031—0.0040 E: 0.0041—0.0100 F: 0.0101 and over

to the rock types, the most representative one occurring in each acid igneous mass is adopted. For instance, if the most representative rock type is granodiorite in certain granitic mass constituted of granite, granodiorite and tonalite, the mark in the figure is shown as granodiorite. In this case the writers used the classification method based on IUGS (1973), however, muscovite-bearing granite is shown by different mark from the other granitic rocks.

The following facts are observed from Figs. 1 and 2.

1. Sr $I$ of more basic types, namely, granodiorite, tonalite, quartz-diorite, diorite, dacite and andesite, have in general low $\sigma$-values.

2. More acid types, namely, granite and rhyolite, have various $\sigma$-values in the range between 0.065* and 0.00008 without concentration in specific range of $\sigma$-value.

3. Muscovite-bearing granites have in general high $\sigma$-values. Moreover, these granites have high Sr $I$ regardless of the $\sigma$-values.

The more basic types having low $\sigma$-values less than 0.0020 are plotted in the same diagram, which is shown in Fig. 3. On the

* the value of $1\sigma$

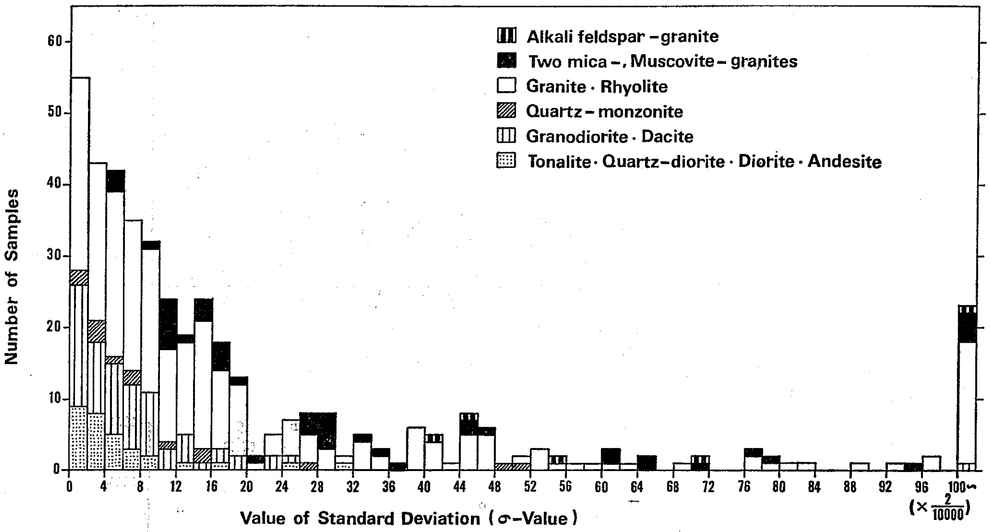


Fig. 2. Frequencies of $\sigma$-values in various rock types of acid igneous rocks.

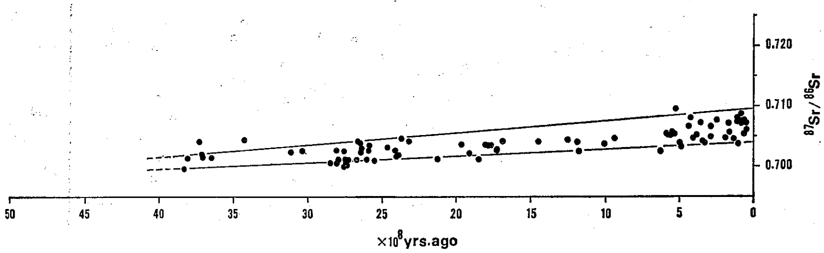


Fig. 3. Relation between the ages and initial Sr isotopic ratios having low $\sigma$-values, 0.0020 and less, as to more basic types.

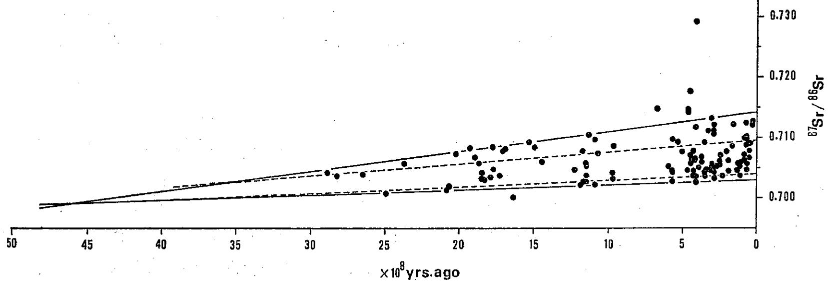


Fig. 4. Relation between the ages and initial Sr isotopic ratios having low $\sigma$-values, 0.0020 and less, as to more acid types. Full lines indicate the upper and lower limits of the field for more acid types. The field of more basic types (see Fig. 3) is shown as dashed lines.

other hand, the more acid types having $\sigma$-values in the same range with those of more basic types are shown in Fig. 4. In the latter figure, the muscovite-bearing granites are excluded.

Comparing with these two figures, the

following facts are clarified.

1. More basic types are plotted in a field narrower than that of the more acid types, the former being situated just above the presumed Sr evolutional field* of the source materials of oceanic ridge tholeiites. The range of the field of more basic types is between ~0.7095 and ~0.7040 at 0 m.y. It is noteworthy that this field almost agrees with the presumed Sr evolutional field of the source materials of continental tholeiite (GORAI *et al.*, 1972).

2. More acid types are plotted in a wider field including that of the more basic types, the range of the field being between ~0.7140 and ~0.7030 at 0 m.y.

### 3. Discussion

In the first place, the relation between the rock types of acid igneous rocks and the $\sigma$-values for the Sr *I* may be stated. As mentioned in the Introduction, the degree of $\sigma$-values may probably reflect certain complicated geological processes such as admixture of sialic materials, secondary alteration and so on, the acid igneous rocks with higher $\sigma$-values having been more strongly suffered from such effects. The fact that more basic types have in general low $\sigma$-values probably suggests smaller effects.

On the other hand, the fact that the more acid types have various $\sigma$-values and do not concentrate in specific range of $\sigma$-values may be interpreted as follows. That is, some granites of low $\sigma$-value have little such effects, while some other granites having high $\sigma$-value are suffered from more effects. Muscovite-bearing granites have in general high $\sigma$-values, moreover, these granites have high Sr *I* even in the case of low $\sigma$-values. The former evidence suggests that muscovite-bearing granites are strongly suffered such geological effects as admixture of sialic materials and so on. The latter evidence, on the other hand, suggests a notion concerning the genesis of muscovite-bearing granites. Thus it may be conceivable that the acid igneous rocks having high Sr *I* are formed from melting of sialic materials constituting the upper continental crust.

Nextly may be mentioned the problem as to the relation between the rock types of acid igneous rocks having low $\sigma$-values and their Sr *I*. As mentioned in Part 2, the field (in the age versus Sr *I* diagram) of more basic types having low $\sigma$-values is similar to that of the Sr evolutional field of the source materials of continental tholeiite. Concerning the source materials of the acid igneous rocks plotted in such field, certain basic material similar to continental tholeiite or basaltic andesite in chemical composition has been assumed (GORAI *et al.*, 1972; KAGAMI *et al* 1975). The basic types under consideration may be derived from certain magma or magmas formed from more advanced partial melting of such basic material. According to SHUTO *et al.* (1975), the Sr isotopic ratios of magma in such advanced stage are nearly equal to those of source materials themselves (see SHUTO *et al.*, 1975, p. 183, Fig. 2).

On the other hand, the field of more acid rock types is wider than that of more basic types. The rocks plotted in the field of more basic types may possibly be derived (differentiated) from certain magmas chemically corresponding to those of more basic types. On the other hand, more acid types plotted above the field of more basic types may perhaps be formed from similar source material in relatively early stage of partial melting (SHUTO *et al.*, 1975).

* The Sr evolutional fields of source materials of continental and oceanic tholeiites have been discussed in detail by GORAI *et al.* (1972), and KAGAMI *et al.* (1975).


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(J) in Japanese, (JE) in Japanese with English abstract

## 酸性火成岩類の岩型と Sr 同位体比初生値との関係

加々美寛雄・周藤賢治・牛来正夫

(要　旨)

筆者らは，酸性岩の岩型 (IUGS : 1973 による)，全岩アイソクロン法によって得られた Sr 同位体比初生値 (Sr *I* 値)，Sr *I* 値についての標準偏差値 ($\sigma$ 値) との関係について考察した．その結果は次のとおりである．① カコウ閃緑岩・トーナライト・石英閃緑岩・閃緑岩・石英安山岩・安山岩などの，より塩基性タイプの岩石は低い $\sigma$ 値をもつ．②カコウ岩・流紋岩などの，より酸性タイプの岩石は種々の $\sigma$ 値をもつ．③白雲母を含むカコウ岩は一般に高い $\sigma$ 値をもっている．$\sigma$ 値の低い値をもつ酸性岩ほど，混成作用・変質作用などの地質的影響が小さいものと考えられる．

$\sigma$ 値が 0.0020 以下の低い値をもつ上記の ①，② の酸性岩について，年代と Sr *I* 値の関係をみると次のことがいえる (第 3・4 図)．① より塩基性タイプの岩石の Sr *I* 値は比較的狭い範囲内にあり，それは大陸性ソレアイトの起源物質の示す Sr 進化帯の範囲とほぼ一致する．② より酸性タイプの岩石の Sr *I* 値は，より塩基性タイプの岩石がしめる帯を含む，より幅の広い帯におさまる．

このような酸性岩の岩型による Sr *I* 値の差異は，地球の創成期に形成されたと考えられる酸性岩の起源物質 (大陸性ソレアイト〜玄武岩質安山岩に化学的性質の類似の物質) の部分溶融の程度の違いによって説明できるであろう．すなわち，第 3・4 図で，より塩基性タイプの岩石の帯の上方をしめる酸性タイプの岩石は，上記起源物質の部分溶融の初期の段階に形成されたマグマから，より塩基性タイプの岩石は，溶融がより進んだ段階に生成されたマグマからそれぞれ形成されたものと考えられる．また塩基性タイプの岩石と同様な Sr *I* 値をもつ酸性タイプの岩石は，塩基性タイプの岩石を形成したマグマの分化作用で生成されたものと考えられる．