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Geochemical evidence for a non-alkalic origin for the carbonatic bodies of Kibuye, Rwanda

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Abstract - The coarse-grained carbonatic bodies of Kibuye have been interpreted as magmatic carbonatites (spathic crystal form, uncomformable contacts, situation along the rift), metamorphozed limestones (occurrence within a sedimentary sequence containing a.o. limestone horizons) or limestones mobilized through magmatic activity (abundance of gabbro-doleritic dykes and sills in the vicinity).

These bodies are made up of nearly pure carbonate, either calcic or calco-magnesian. They are R.E.E.-, Ba- and Sr-poor, thereby precluding any magmatic alkalic affinity. Their $^{87}Sr/^{86}Sr$ ratio of 0.71141 is likewise too high for a mantellic filiation. This ratio is however intermediate between those shown by the gabbro-dolerites and some dolomitic phyllites of the Burundian Sequence (Middle Proterozoic), which have respectively yielded 0.70991 and 0.71250 (when corrected for 1400 M.a. of ^{87}Rb decay).

The latter values, together with the ^{18}O and ^{13}C ratios, suggest that the origin of the carbonatic bodies must be searched for in a process where sedimentary dolomites have been remobilized, probably under the influence of the magmatic intrusions. Although situated in the vicinity of the Western Rift, as many other alkalic complexes, the carbonatic rocks of Kibuye are not representatives of this magmatic kindred.

INTRODUCTION

Because of their situation along the western branch of the East African Rift system, the carbonatic bodies of Kibuye constitute possible elements of a chain of alkalic complexes emplaced between the northern end of Lake Malawi and a region situated south of Lake Mobutu (Fig. 1). The properties of these rocks and the assessment of their actual nature are therefore of prime importance for the understanding of the magmatic evolution coeval with the tectonic development of the Rift.

Several types of carbonatic rocks are known in the neighbourhood of Kibuye and lake Kivu (Verhaege, 1963).

1. Subrecent tuffa resulting from the activity of thermal springs the water of which has leached e.a. calcium from the Precambrian formations (see below) through which they have passed, following fractures linked to the development of the rift (Buyagu, 1979, 1980).

2. Calcareous material, sometimes constituting centimetric lenses, in the quartzitic or quartzo-phyllitic members of the Lower division of the Middle Proterozoic Burundi Group (see below) and dolomitic horizons interbedded with the pelitic members of the same group (Buyagu, Dehandschutter and Trefois, to be publ.).

3. Carbonatic bodies constituting characteristic members of an alkalic complex. i.e. carbonatites. The nearest examples are the Kirumba (Denaeyer, 1966) and Lueshe (a.o. Maravic and Morteani, 1980) complexes situated in Zaire (respectively 70 and 110 km to the north-west), on the other side of the rift valley, and the Upper Ruvubu alkalic complex (Tack *et al.*, 1984) situated 100 km southwards in Burundi (Fig. 1).

4. Carbonatic bodies constituting well individualized units showing no direct link with magmatic alkalic complexes. Such bodies are known on both sides of Lake Kivu. The existence of the Kibuye bodies has been reported to the Geological Survey by B. Egoroff during the '50s and they have subsequently been studied (Meyer, 1957) and economically assessed (a.o. Neubauer, 1968). It is mainly these rocks that we shall be dealing with. The Kawizi body (Kivu) has been described and recognized as non-magmatic by Denaeyer (1970).

The Kibuye bodies have been interpreted as magmatic, carbonatite-like intrusions by Meyer (*op. cit.*), mainly on the basis of their association with gabbro-dolerites, as carbonatites *sensu stricto* by Maravic and Morteani (*op. cit.*), probably following Meyer, and by Denaeyer (1970) who noted however their peculiar isotopic geochemistry. These authors have indeed been considering them in the dynamic frame of the

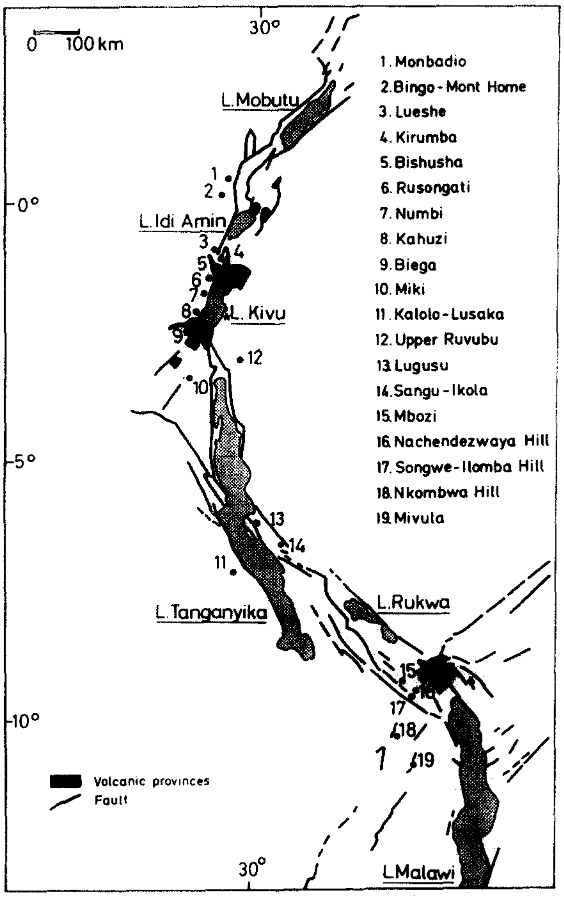

Fig. 1. Spatial distribution of alkalic units located along the western branch of the East African Rift (from TACK *et. al.*, 1984). Kibuye is indicated by a *.

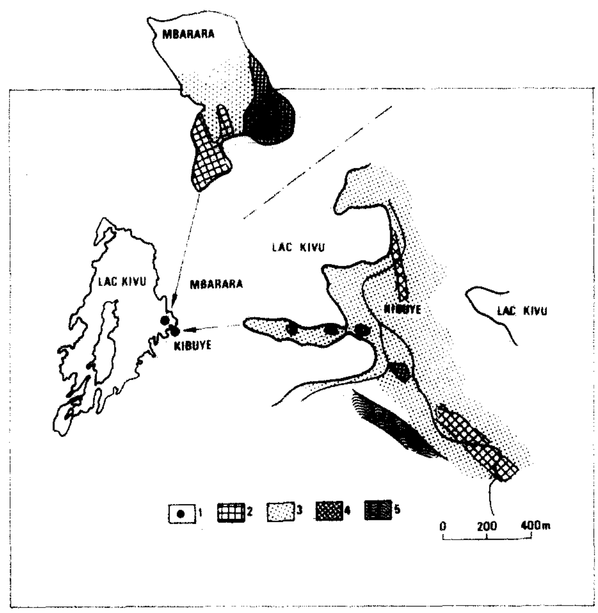

Fig. 2. Sketch map showing the main lithologic units and the situation of the carbonatic bodies near Kibuye. The sub-conformable position of these bodies and the constant vicinity of the gabbro-dolerites is stressed. Legend: 1. locality; 2. gabbro-doleritic sills; 3. metapelites and 5. quartzites of the Middle Proterozoic Burundi group; 4. carbonatic bodies.

carbonatites (of various ages) the existence of which was presumed to be linked with the development of the Rift and its volcanic province (Fig. 1). On the basis of the existence of recognized carbonatic sediments in the vicinity (2. above), they have been interpreted as metamorphozed limestones by Bertossa and Neubauer (1970), but this hypothesis has not gained unanimity.

DESCRIPTION AND GENERAL GEOLOGY

The carbonatic bodies of Kibuye form three small (some 100 to 300 m^2, 10 to 25 m high) hills situated north and south of the harbour of Kibuye, and also part of the islet of Mbarara to the northwest of it (Fig. 2).

They are built up by coarse grained spathic dolomite. The crystals are usually 2 to 4 cm large. The body situated north of the harbour also shows tremolite and is cut by veins of calcite with some pyrite. The contact between the bodies and the country rock is uncomformable (non-interbedded) with the metasediments of the Middle Proterozoic Burundi Group or with the metadolerites (originally gabbro-dolerites) sills emplaced into them. These metadolerites are always found in the vicinity of (not necessarily in contact with) the carbonatic bodies. Indications of metamorphism have been reported, as well as the presence of muscovite-schists and dolomite inliers (Bertossa and Neubauer, *op. cit.*, Buyagu, 1980).

Along the western limit of the northern body, a microcrystalline rock made up of 90 % albite and quartz in myrmekitoid association with hematite has been observed. No indication of fenitization or other form of metasomatic activity has been noted.

The Lower and Middle divisions of the Burundi Group, outcropping in western Rwanda are made of a succession of quartzites and pelites locally metamorphozed in the greenschist facies to quartzites of variable grain and purity and grey, black or green lustrous phyllites, locally with blasts of biotite or garnet. Voluminous doleritic sills and dykes (auto ?) metamorphozed to amphibolo-dolerites (metadolerites) cut trough the succession in the vicinity of Kibuye. One or two metric horizons of the Burundian sequence show centimetric to decimetric alternations of quartzo-pelites with carbonatic material; some inter-stratified dolomites are also known.

Granites, aplites, pegmatites and quartz-veins, sometimes tin-bearing, cut through the sedimentary sequence north and south of Kibuye. Their intrusion results in the development of muscovite and tourmaline in the metasediments situated nearest to the contact, and in the blastesis of biotite and garnet farther from it.

The geochronological pattern of the region is quite constrained. The lower division of the

Burundi Group has been deposited (in Burundi, but the situation should not be different here) around 1.4 Ga ago. The Burundian sequence comprising the metadolerites has been subject to several tectonic phases, the last of which is 1100 M.a. old, the others about 1.3 and 1.2 Ga. The so-called tin granites are 980 M.a. old (ages compiled in Lavreau, 1984).

GEOCHEMISTRY OF THE CARBONATIC ROCKS

Major elements

The analyzed samples belong to the main carbonatic body (Fig. 2). They are almost purely carbonatic with an amount of tremolite and more rarely oxidized pyrite varying between 0 and 10 %. The purest members shows a MgO to MgO + CaO ratio of 0.39 and a FeO to FeO + MgO ratio of 0.17. The rock is thus made of ferroan dolomite (Table 1), i.e. a rather rare type (especially when it is the only carbonatic rock present) among carbonatites (the Kirumba carbonatite is for instance much richer in Fe, *cf.* Denaeyer, 1966).

This purity in non-carbonatic elements can be compared with values obtained on well documented magmatic carbonatites and compiled by Gold (1966, in Le Bas, 1981); the low values displayed by the Kibuye rocks in Ti, Fe, Na, K and P are striking and confirm the lack of silicate minerals evidenced in the field (Table 1).

Trace elements

Some elements which are diagnostic for carbonatites have been analyzed (Table 1). Sr, Ba and the R.E.E. (represented by Y, La and Ce) are generally lower by a factor of 10 or 100 in the carbonatic rocks of Kibuye than in carbonatites; it is particularly clear in the case of Sr (40 to 100 ppm as compared with the 3000 to 6000 ppm which may be expected in the magmatic types) (*cf.* Kaputsin, 1983).

Sr isotopes

The isotopic composition of the strontium of the carbonatic rocks, the metadolerites .and the metasediments has been determined (Table 2).

Three carbonatic rocks have yielded values between 0.71127 and 0.71152, with an average of 0.71141 ± 0.00013 for the $^{87}Sr/^{86}Sr$ ratio. The metadolerites (one sample) show an initial ratio of respectively 0.71010 ± 81 or 0.70991 ± 86 (± from analytical data only), after correction for the decay of ^{87}Rb during 1.2 or 1.4 Ga. (When using the Sr ratio of the carbonatic rocks as initial ratio, the "age" of the intrusives is 1009 M.a; because of the low content in Rb of the metadolerites, the incertitude on that age is quite high: 189 M.a.).

Table 1. Chemical composition of the Kibuye carbonatic rocks compared with reputed magmatic carbonatites ("Average") compiled by Gold (1966). The lower content of diagnostic major and trace elements displayed by the Kibuye samples is striking.
(Analyst: R. Kool, MRAC, Tervuren).

	Kibuye 5 samples range	Average Gold (1966)
% SiO_2	0.9 - 1.6	5.67
TiO_2	0.0 - 0.1	0.50
Al_2O_3	0.05 - 0.1	1.77
F_2O_3t	0.1 - 0.3	8.00
MnO	0.07 - 0.15	0.78
MgO	18. - 20.	6.17
CaO	29. - 30.	37.06
K_2O	0.01 - 0.02	0. 87
Na_2O	0.1 - 0.2	1.09
P_2O_5	0.13 - 0.18	1.73
ppm Sr	44. - 101.	7500.
Ba	4. - 10.	400.
La + Ce	7. - 28.	5300.
V	8. - 12.	105.
Y	5. - 71.	114.

A metasedimentary dolschist (one sample) yields a ratio (when the same correction is applied) of 0.71296 ± 50 or 0.71250 ± 53 (when calculated as above, its «age» is 1523 ± 66 M.a., a value well in keeping with the presumed age of the host rocks, *cf.* Lavreau, *op. cit.*).

The ratio yielded by the carbonatic rocks is thus situated in between the initial Sr ratio of the metadolerites and that of the metasediments.

The Sr ratio of the carbonatic rocks of Kibuye is far above the carbonatitic (and the mantle) values which are usually below 0.705 (Pineau *et al.*, 1973), averaging around 0.7035 (Powell *et al.*, 1962). For instance, the carbonatites associated to the *ca.* 750 M.a. old foidal intrusive complex of the Upper Ruvudu in Burundi have yielded a value of 0.7032 (Tack *et al.*, *op. cit.*, Midende, 1984). Such rocks are indeed, because of their high Sr content, not sensible to contamination by ^{87}Sr-rich rocks or fluids. If carbonatic rocks show a high Sr ratio, this ratio must thus directly reflect the composition of a non-mantellic source.

O and C isotopes

The $\delta^{18}O$ and $\delta^{13}C$ ratios of the carbonatic rocks of Kibuye were measured some time ago (Denaeyer, 1970). The values obtained, respectively 12.7/10^3 (relatively to SMOW) and -12.6 permil (DPD) fall outside of the range of the magmatic carbonatites of Taylor and also out of the range of the carbonatic rocks of sedimentary origin (Fig. 3).

DISCUSSION

The intrusive, or at least the foreign character of the carbonatic bodies within the sedimentary sequence may, together with the homogenity and absence of structure of these rocks, appeal for a magmatic origin.

Several facts point however towards a non-magmatic, and particularly non-alkalic, origin for these bodies :

Table 2. Rb, Sr contents (ppm) and isotopic ratios of strontium of a carbonatic rock of Kibuye, a gabbro-dolerite and a metasediment (dolschist).

The isotopic ratios have also been recalculated at 1.2 and 1.4 Ga, thus encompassing an important event in the Kibaran orogeny and a date near to the beginning of this period, according to the present-day Rb content. The "ages" given below are calculated using the ratio of the carbonatic rocks as initial Sr ratio.

	Rb	Sr	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr$
Carbonatic Rock	2 ± 2	101 ± 2	< 0.12	0.71141 ± 3
Amph Dol. At 1.2 Ga At 1.4 Ga	13.5 ± 2	148 ± 2	0.264 ± 2	0.71521 ± 4* 0.7107 ± 8 0.7099 ± 9
Dol Schist At 1.2 Ga At 1.4 Ga	62 ± 2	289 ± 2	0.6218 ± 26	0.72499 ± 5** 0.7143 ± 1 0.7125 ± 1

For Ri ≡ 0.7114
* Age : 1009 + 189/- 142 M.a.
** Age : 1523 ± 66 M.a.

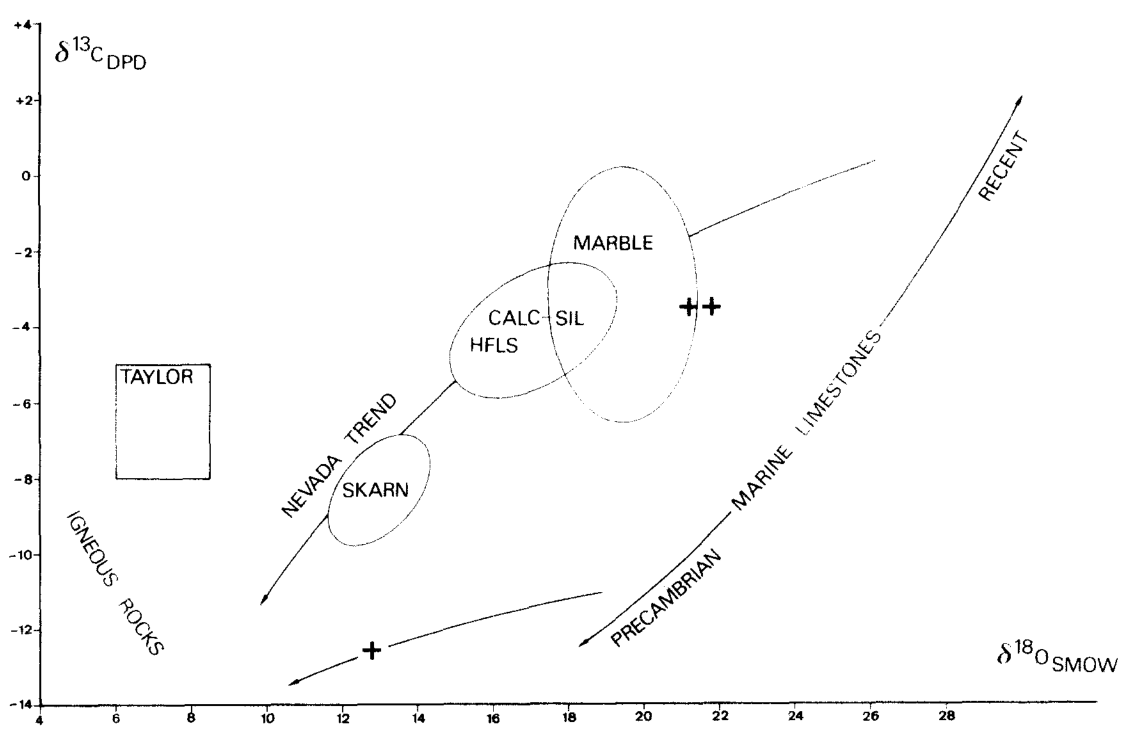

Fig. 3. $\delta^{13}C$ versus $\delta^{13}O$ diagram showing the position of the representative point of the carbonatic rocks of Kibuye (+) and Kawizi (++) (Denaeyer, 1970) relatively to the field of carbonatites (Taylor's quadrangle), igneous rocks and marine limestones. The actual position of the Kibuye point, situated between the fields of the Precambrian limestone and that of the igneous rocks, is compared with the position of MARBLEs, CALC-SIL HFLS (calc-silicated hornfels) and SKARNs from Nevada, similarly situated between the igneous and the Recent limestone fields (data compiled from O'Neil, 1979 and Wedepohl, 1978). The Kawizi point similarly lies on the line tying recent limestones to the magmatic region

1. the absence of alkalic intrusions or fenitization phenomena in the vicinity;
2. a major element chemistry rather different from that of reputed carbonatites;
3. a minor and trace elements chemistry very different, especially in elements considered as diagnostic, from that of carbonatites;
4. Sr, O and C isotopic ratios falling far out the magmatic range.

These facts and observations can be reconciled in a model where carbonates from carbonate-rich sediments (like the dolschists of the Burundi Group) get mobilized under the influence of relatively hot and fluid-rich intrusives to give rise to a marble or skarn body, i.e. a process not very different from the one presented by Bertossa and Neubauer *(op. cit.)* and documented on field observations.

The observed Sr isotopic ratio, intermediate but near to both sediments and intrusives and thus taking a possible admission of ^{87}Sr from the magma into account, fits also well in such a scheme.

In a $\delta^{18}O$ versus $\delta^{13}C$ diagram, the values for igneous rocks (and the carbonatites) are situated in the lower left region, whereas the values for the sediments are spread from the upper right (Phanerozoic to Recent limestones) to the lower right (Precambrian limestones) regions (Fig. 3), whereas the representative point for the Kibuye carbonatic rocks lays on a line tying the igneous field to the field defined by the limestones of Precambrian age. This situation reminds us of the observation in limestones from Nevada, with a similar geological environment , where a "marble", presumably equivalent to the Kibuye rocks, is also situated on a line tying the igneous field to the limestones (Recent in this case), with "skarn" and "calc.-silicate hornfels" as intermediate points (Taylor and O'Neil, 1977). It may be worth noting that the Kawinzi carbonatic rock, considered as non-magmatic and recent by Denaeyer (1970), similarly plots between "recent" limestones and igneous rocks (Fig. 3).

The carbonatic rocks of Kibuye have a much lower content in some trace elements than carbonatites do; their content is however also lower than in the dolschists and other sediments. The studied rocks are thus not isochemical variants of the dolschists (the structure and field relations point moreover to the contrary). Some leaching process must be invoked, aiming at giving rise to a separate rock body akin to a gigantic carbonate concretion. The fluids responsible for this process are most probably connected with a magmatic activity. Possible candidates for such an activity are, on the one hand, the granitoids belonging to one or other of the three or four generations of intrusions emplaced during the Kibaran orogeny or, on the other hand, the gabbro-dolerites which are so abundant in the area around Kibuye.

Kibaran gneissic granites outcropping 10 km south of Kibuye have yielded an age (the signification of which is not entirely certain but which corresponds most probably to a tectonic event) of 1135 ± 43 M.a. and an initial Sr ratio of 0.7176 ± 0.0012, whereas the "tin granites" have given 988 ± 27 M.a., 0.7657 ± 0.0074 (Lavreau et Liégeois, 1982). The latter are too young, but the gneissic granites constitute suitable source rocks; the amount of fluids which have been released by these granites is testified by the abundance of hydrated minerals developed in the wall-rocks of the intrusions.

On the other side, several arguments point to the gabbro-dolerites as source rocks for the fluids: their vicinity and constant association with the carbonatic bodies, the local presence of tremolite in the carbonatic bodies and their adequate Sr isotopic ratio.

CONCLUSION

The carbonatic bodies of Kibuye can hardly represent magmatic carbonatites of alkalic filiation. Their origin must be searched for in a mobilization process affecting sedimentary dolomites, probably caused by hot fluids released by intrusive granites or gabbro-dolerites, not long after their intrusion.

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