inclusive graphic standard deviation (s_I) vary from 4.2 to 6.4 and 3.1 to 4.2 respectively. The logarithmic plots of the coarsest one percentile versus median particle size make a distinct rectilinear pattern. Taking into account the overall lithological and textural features, this gravelly horizon appears to have formed by the process of debris flow[5]. The gravel has several sand lenses and is overlain by a 3 m thick coarse to medium stratified sand layer.

The gravel that overlies the sand is characterized by subangular to rounded clasts (cobble to sand size). Well-defined stratification, interbeds of fine gravel or sand, graded bedding (both normal and inverse) imbrication and carbonate cement, points to its being a stream flow sheet deposit[6]. The uppermost gravel again shows features of debris flow. Grading is not visible, stratification is very poor and the clasts are mainly cobbles and pebbles. A distinct laminated mud and or sand horizon separates it from the underlying gravel.

The categorization of the three gravelly horizons into debris flow and stream flow lithofacies types has considerable significance from the point of view of the mechanism and the process of deposition in LNV, which, in turn, reflect the variations in the climate. During wet spells the Narmada river and its tributaries have carried the clasts and deposited them in the graben. The clasts are dominantly locally derived from nearby areas. The alluvial deposits in LNV vary greatly in lithology and show a decrease in clast size and progressive change in internal sedimentary structures in the downstream direction. Further, they are formed by more than one process and the proportions of different types of deposits vary both vertically and downslope.

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Stable isotopic evidence for the pedogenic origin of calcitic rocks of Andaman–Nicobar Islands, Bay of Bengal, India

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Carbon and oxygen isotopes and electron microprobe analyses were carried out in some calcitic outcrops of the Andaman–Nicobar group of islands. Isotopic results in these rocks indicate significant depletion in $\delta^{13}C$ (−12.0 to −15.02‰ vs PDB) and low $\delta^{18}O$ values (18.42 to 23.32‰ vs SMOW). The presence of chromite, magnetite, quartz and chlorite relicts in the microprobe analyses and other geological features suggest that they were formed by the alteration of ultramafic rocks. Brecciation and cementation of the ultramafics under the influence of meteoric water are attributed to the formation of these calcitic lenses.

THE Andaman–Nicobar group of islands constitute an island arc connecting the Arakan-Yoma range of western Burma to the festoons of islands south and west of Sumatra. These islands were uplifted during collisional events associated with the subduction of Indian plate under the Eurasian plate[1,2]. The arc system is composed of an inner volcanic arc and an outer sedimentary arc. The ophiolitic suite of these islands consists of Plutonic igneous rocks, ultrabasics and volcanics[3]. The sedimentary rocks which occur in the south Andaman island are mainly composed of radiolarian cherts, conglomerates and grit, and turbidites[3,4]. The radiolarian cherts which occur as thin bands consist of radiolarian tests set in the fine-grained clay matrix[4]. Mineralogical studies carried out in these clays showed that they are mainly made up of montmorillonite and chlorite minerals[4]. Conglomerates and grit unit include interbedded calcareous shales and sandstones[3]. Turbidites cover most part of the south Andaman island and comprise alternate greywackes, siltstones and shales. They have well-developed sedimentary structures like graded bedding, flow casts, load casts, convolutes, etc.[3]. Geological and geochemical studies of these sediments suggest that they were deposited under different oceanic environments[4,6]

The calcitic outcrops of the south Andaman are exposed in small lenses in association with ultramafics and serpentinous rocks. These lenses which were reported earlier as 'hard crystalline limestones' are different from other shell carbonates and limestone boulders of these islands[5,6]. These islands are extensively covered by forests and receive a very heavy annual rainfall of about 3800 mm

Table 1. Electron microprobe data of the two samples from South Andaman island

	AN-6 (i)						AN-87 (i)						
Oxide wt %	Coarse grain calcite	Fine grain calcite	Chromite	Magnetite	Chlorite	Mg-calcite	Coarse grain calcite	Fine grain calcite	Chromite	Magnetite	Mg calcite	Quartz
SiO_2	0.20	1.18	0.05	1.75	29.75	0.08	0.02	0.26	0.05	3.52	1.25	95.76
TiO_2	0.03	–	0.39	0.60	–	0.02	0.01	0.05	0.02	–	0.09	0.02
Al_2O_3	0.05	0.15	28.50	–	12.67	–	–	0.36	31.46	–	0.01	0.39
FeO(T)	1.53	8.30	16.50	88.29	22.71	6.64	0.26	2.36	18.57	90.43	4.52	0.47
MnO	1.15	1.67	0.13	0.19	0.13	1.46	0.83	1.54	0.14	0.01	2.11	–
MgO	0.65	1.60	14.35	0.27	14.99	13.45	0.31	1.70	13.62	1.83	14.03	2.94
CaO	57.51	44.26	0.33	0.93	0.46	36.31	60.96	55.89	0.34	0.74	37.46	0.10
Na_2O	–	0.14	–	0.04	0.07	0.09	–	–	–	–	–	–
K_2O	0.04	0.04	0.04	0.04	0.09	0.03	0.04	0.03	0.04	0.06	0.04	0.04
Cr_2O_3	–	0.02	38.58	0.13	2.36	0.04	–	–	33.93	–	–	0.02
Total	61.16	57.36	98.87	92.24	83.23	58.12	62.43	62.19	98.17	96.59	59.51	99.74

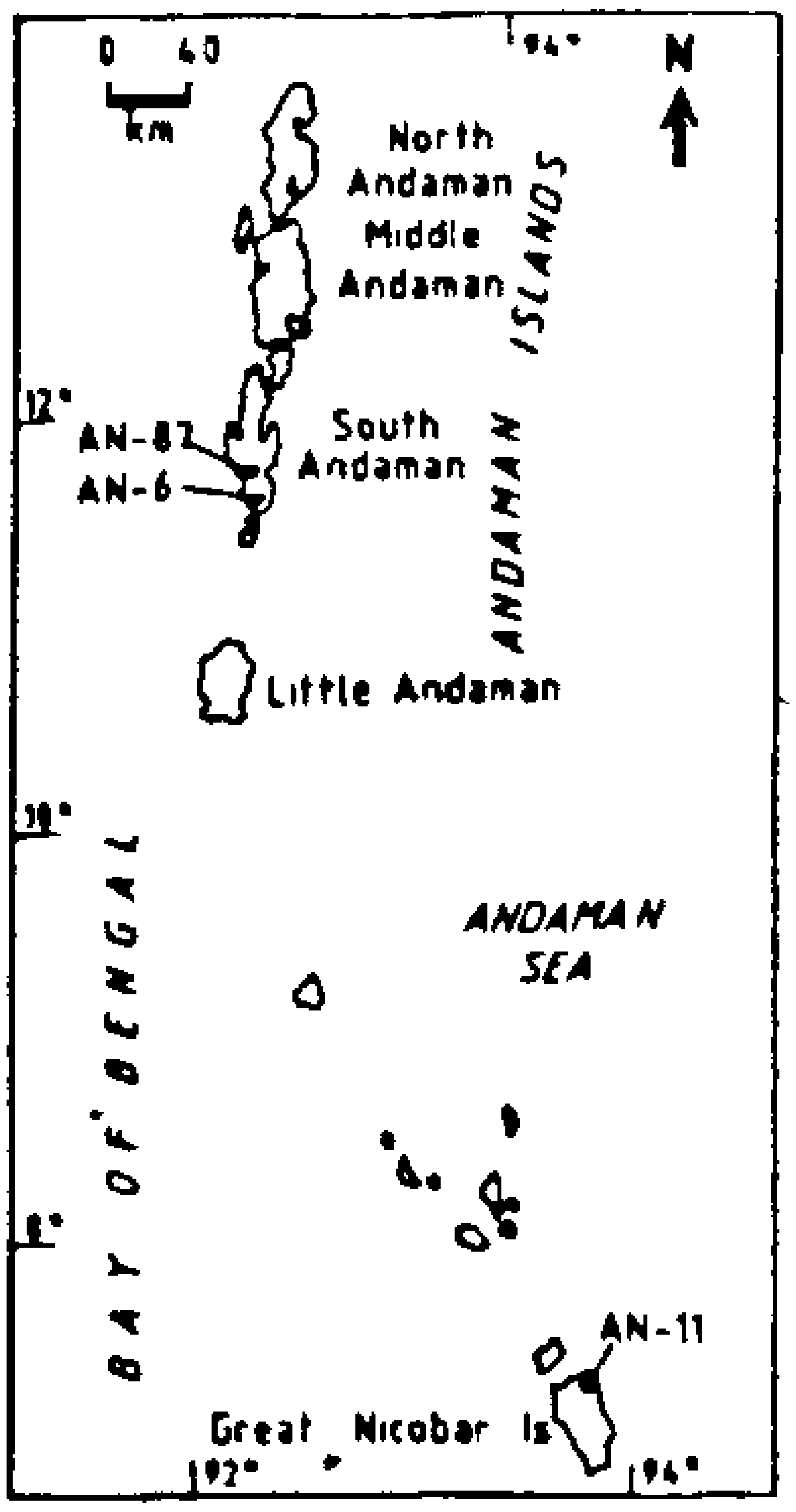

Figure 1. Sampling locations. Samples from three outcrops are shown in the map as AN-6, AN-11 and AN-87.

Carbonates formed as a result of freshwater diagenesis have low $\delta^{13}C$ and $\delta^{18}O$ values[7, 8]. The $\delta^{13}C$ values of carbonates formed by meteoric waters are lower than marine carbonates because their $^{13}C/^{12}C$ ratios depend on the isotopic composition of dissolved CO_2 in which carbonates are precipitated. The different sources of carbon contributing to isotopic signatures in such carbonates are the atmospheric CO_2, CO_2 derived from organic matter and dissolution of carbonates[9]. Therefore the depleted $\delta^{13}C$ values in freshwater carbonates are mostly due to the addition of CO_2 derived from the oxidation of organic matter[10]. The tropical rains are also depleted in $\delta^{18}O$ (because of high humidity) and therefore the carbonate formed by meteoric water is expected to have low $\delta^{18}O$ values[11]. However, rocks which are completely altered to calcite were reported as isotopically inhomogenous[12]. Stable isotopes of hydrothermal calcites from eastern Sweden have very low $\delta^{18}O$ (10.0 to 13.0‰ vs SMOW) as compared to their $\delta^{13}C$ (–2.5 to –6.0‰ vs PDB) values[13]. Similarly carbonate rocks of the deep-seated origin can be characterized by their $\delta^{13}C$ values which lie in the range of –2 to –8‰ vs PDB while marine carbonates exhibit $\delta^{13}C$ range of –1 to +2‰ vs PDB[7, 14].

A pedogenic transformation of serpentine peridotite under subaerial conditions was proposed for the formation of ophicalcites of Liguria, Italy[15]. Stable isotopes of calcitic rocks of Apennine complex of Italy were used to conclude their marine origin[16]. The weathering of ultramafics of the red mountains by meteoric water has resulted in the lowering of $\delta^{13}C$ of the vein carbonates[17].

Samples were collected from two outcrops of the South Andaman and one outcrop of Great-Nicobar islands (Figure 1). Petrographic studies were carried out in all the samples of these outcrops while two samples from south Andaman were analysed by electron microprobe. The microprobe analysis was carried out by the wavelength dispersive electron microprobe (Camebax-Micro) using both synthetic and natural standards.

The other set of 11 samples representing all the three outcrops were ground to fine powder for stable isotope measurements. Sample powders were reacted with 100% H_3PO_4 and the evolved CO_2 was then introduced into the mass spectrometer (VG 602-D) to obtain isotopic ratios[18]. The results of isotopic measurements are reported in standard δ notation relative to PDB and SMOW standards for carbon and oxygen respectively. Precision for the carbon was better than ±0.10‰ and for oxygen ±0.15‰.

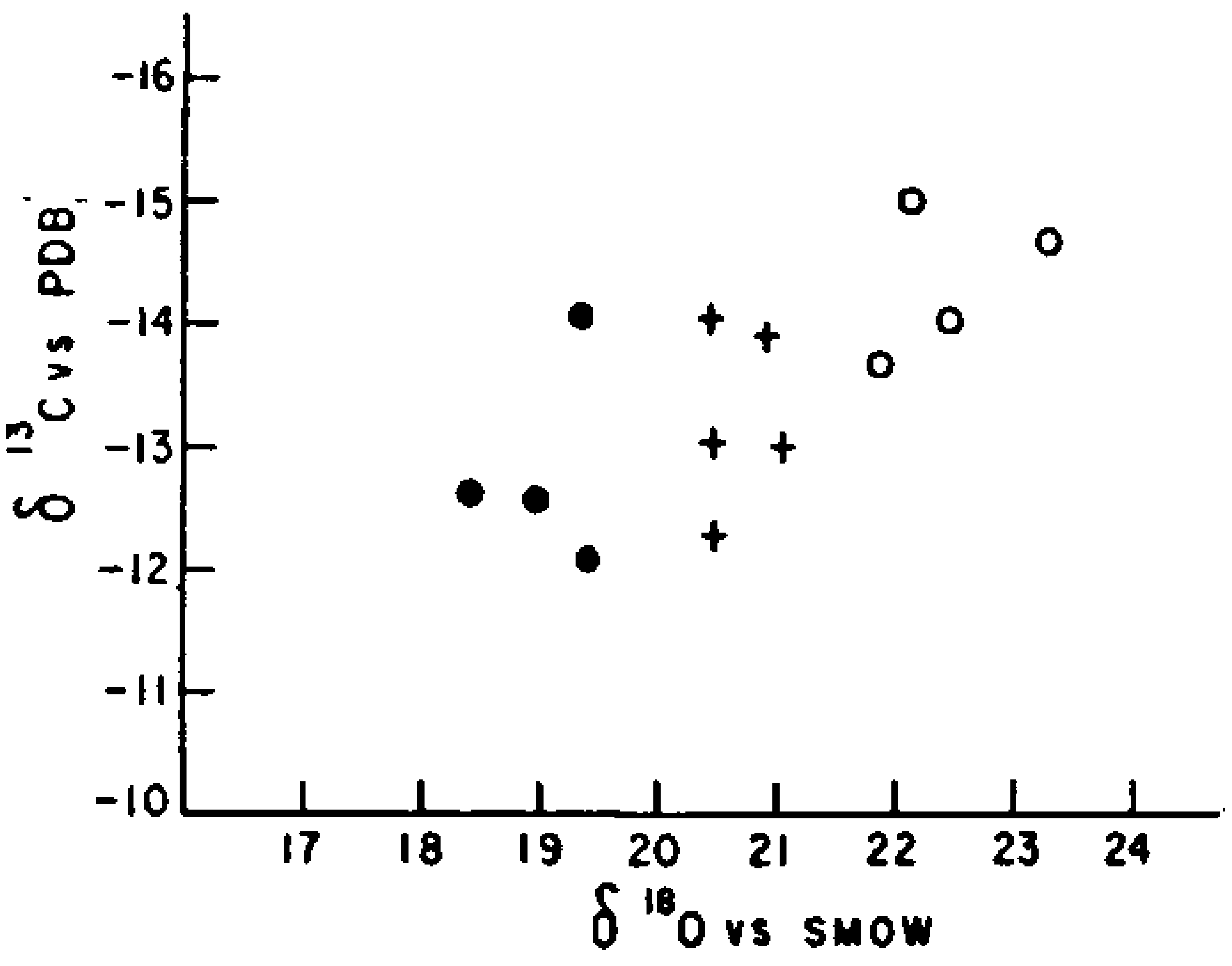

Figure 2. $\delta^{13}C$ [PDB] versus $\delta^{18}O$ [SMOW] diagram, representing '+' and '•' for south Andaman samples while 'o' represents samples from Great-Nicobar

The electron microprobe data (Table 1) and petrographic studies indicate the following features: (a) Relicts of parent rock minerals like chromite, magnetite, quartz and chlorite are present in samples of south Andaman and Great-Nicobar. (b) The carbonate matrix has the texture of clastic mud and constitutes about 70–80% of the rock volume. (c) Sparry calcite crysfals are present in vein structures and dolomite is relatively more abundant in the samples of Great-Nicobar. (d) No evidence of any microfossil.

Stable isotope data suggest significant depletion in $\delta^{13}C$ values (–12.0 to –15.02‰ vs PDB) and relatively low $\delta^{18}O$ values (18.42 to 23.32‰ vs SMOW) (Figure 2). The isotopic data and petrographic studies indicate that these rocks were probably derived by pedogenic transformation of ultramafic or serpentinous rocks under the influence of meteoric waters. Hydrothermal origin can be ruled out because the data show highly depleted $\delta^{13}C$ and somewhat enriched $\delta^{18}O$ values than expected for the hydrothermally derived carbonates.

Brecciation of the parent ultramafic rock could have been followed by cementation process. Breccias can result in this region of shearing by tectonic movement caused by accreting plates. Subsequently the rocks were exposed to subaerial environment and meteoric water may have caused the alteration of ultramafic rock fragments. As suggested earlier[17], cementation process could involve two types of fluids emanating from ultramafic rocks, the predominantly $Ca^{2+}OH^-$ and $Mg^{2+}HCO_3^-$. However, their isotopic signatures were reported to be similar[17]. Our isotopic data are in excellent agreement with both the calcite formed involving such fluids and to vein calcites formed by meteoric waters[13, 17].

In conclusion, the isotopic and mineralogical studies of these rocks suggest that they were formed by brecciation and cementation of ultramafic rocks under the influence of meteoric water at or near surface temperatures.

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A new graphical representation and analysis of DNA sequence structure: I. Methodology and application to globin genes

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A novel graphical approach is proposed for representing DNA sequences in a two-dimensional cartesian