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A possible impact origin for the Bangui magnetic anomaly (Central Africa)

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ABSTRACT

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Bangui is one of the most impressive magnetic anomalies on Earth and by far the largest over Africa. At Magsat altitudes, it has an amplitude of 28 nT and covers an area of 700,000 km^2. Evidence presented suggests that the anomaly might be related to a large impact structure early in the history of the Earth: north–south, west–east, and vertical derivatives of the 5-min topographic data base all reveal a double ring structure with outer ring diameter $\sim$810 km and inner ring diameter $\sim$490 km. The Precambrian geology shows several small ancient basins within a large basin with a basement high in the middle such as found in large impact structures. The basement complex is early Precambrian and hence the impact must be of this age. The magnetic anomaly is interpreted as being due to strong remanent magnetism in the ancient crater floor and surrounds. The anomaly can be satisfactorily modelled by a 4.5-km-thick disc, 800 km in diameter beneath the ancient basins. To model the amplitude and shape of the anomaly requires an intensity of 10 A m^{-1} with direction $D =$ N 18°W, $I = +25°$, i.e., significantly different from the present dipole field. The magnetisation is likely to include strong shock remanence (SRM) acquired at the time of impact, thermal remanence (TRM), partial thermal remanence (PTRM), thermochemical remanence (TCRM) and chemical remanence (CRM) acquired soon after the impact. All depend on the size of the impact and all contribute to the high intensity required to explain the anomaly.

Introduction

The Bangui magnetic anomaly is one of several crustal magnetic anomalies which has been mapped using satellite data. The largest satellite magnetic anomalies are found over the continents and are circular to elliptical in shape with amplitudes typically 10 to 20 nT. All the continents have anomalies, one of the largest being over Antarctica centred at 70°S, 130°E. In contrast, there are few satellite magnetic anomalies of appreciable size over the oceans.

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The Bangui anomaly

The Bangui anomaly is by far the largest magnetic anomaly over Africa. It was first observed in 1953 from surface measurements (Godivier and Le Donche, 1956). In 1960, Project Magnet flew two profiles across the anomaly at an altitude of approximately 3 km (Stockard, 1970). These showed the anomaly to have an amplitude of at least -1000 nT and a width of at least 530 km (Green, 1973, 1976). In 1964, measurements of the scalar magnetic field made from the satellite Cosmos 49 revealed the Bangui anomaly in excess of -40 nT at a mean altitude of $\sim$350 km (Benkova et al., 1973). The Bangui anomaly as seen on global magnetic maps derived from POGO and Cosmos 49 satellite magnetometers is discussed in an abstract by Regan et al. (1973) and the maps are presented in Regan et al. (1975).

The large areal extent of the anomaly became apparent from satellite data. Table 1 lists various observations of the anomaly. The anomaly is centred at 6°N, 18–20°E, with a diameter of about 1000 km (measured north–south between zero contours) and has amplitudes -10 to -20 nT for satellite data reduced to heights 400 to 500 km.

The satellite magnetic anomaly map used here is constructed from Magsat data. Forty dusk and eighteen dawn orbits were used, the orbits varying in altitude between 365 and 385 km. Adjustments in bias and slope were made to minimize the errors at orbit intersections using the method of Taylor and Frawley (1987). The resulting total intensity magnetic anomaly map computed for an altitude of 375 km is shown in Figure 1. It is seen that the Bangui anomaly is centred at 6°N, 18°E, has a north–south diameter of 760 km and reaches -22 nT.

There are also ground measurements in this region (Godivier and LeDonche, 1956; Vassal, unpublished data 1978). These are described by Regan and Marsh (1982). A smoothed map of the ground total intensity magnetic anomalies shows a minimum in excess of -1000 nT centred at 6°N, 20°E, whilst a detailed contour map of the observations shows the negative anomaly split into two with a negative of -1600 nT centred at 6°N, 20.2°E and the second negative of -1000 nT centred at 6.1°N, 20.8°E. There are three small but intense positive anomalies to the southeast. The anomaly is therefore present in satellite, airborne and ground data.

Previous interpretations

The large area (700,000 km^2) and large amplitude (> 20 nT) of the Bangui anomaly at satellite altitudes make it one of the most impressive magnetic anomalies on Earth. Its interpretation is thus of great interest.

Green (1976) in a study of Project Magnet profiles over Africa noted from the smoothness of the long-wavelength anomaly and lack of short-wavelength magnetic relief, the source must be fairly deep. He also noted: (1) there seems to be no obvious relationship to the surface geology of metamorphic and sedimentary rocks; and (2) the deep-seated causative body must be highly magnetic, normally magnetised and very extensive. This led him to propose two possible explanations: (1) the causative body might be related to some iron meteoritic material which for some reason failed to sink and differentiate into the core; and (2) there could have been a major upwelling of ultrabasic magma which cooled in an exceptionally favourable environment for the production of highly magnetic minerals.

The first possibility has been considered further by Ravat (1989) who proposed a high-susceptibility body at 4–7 km depth described as "Fe–Ni-rich meteorite or Fe-rich iron formation" to replicate the Magsat anomaly.

The second possibility was explored by Regan and Marsh (1982) who opted for a large mafic

TABLE 1

Observations made on the Bangui anomaly

	Centre (lat., long.)	Diam. [a] (km)	Ampl. (nT)	Alt. (km)	Reference
Ground survey	6°N, 20°E	> 200	−1500	0	Vassal, 1978 (unpubl.)
Project Magnet	5–6°N, 18–20°E	–	> −1000	3	Green, 1976
5° Av. Cosmos 49	6°N, 20°E	> 1250	> −20	375	Regan et al., 1975
Pogo	4°N, 19°E	1010	> −10	540	Regan et al., 1975
Pogo	5°N, 18°E	1060	> −12	525	Regan and Marsh, 1982
Magsat	5°N, 18°E	~ 800	−13		Hastings, 1982, fig. 1
Magsat	6°N, 20°E	~ 800	−16		Hastings, 1982, fig. 2
Magsat	6°N, 18°E	760	−22	375	This paper

[a] Estimated north–south from 0 to 0 contours.

pluton intruded into the crust beneath the Oubangui sedimentary basin. They envisaged that a dense, voluminous, highly magnetic intrusive body rose into the crust, grew denser with cooling, and then isostatically settled, warping down the crust to form the Oubangui sedimentary basin. Such an intrusion might be expected to have a large positive gravity anomaly, whereas in fact, the region has a large negative Bouguer anomaly reaching -110 mGal, coinciding with the magnetic anomaly. Regan and Marsh considered this negative gravity anomaly to be caused by the basin filling sedimentary rocks and the root of the intrusive body protruding into the mantle. Their computer model thus essentially consists of two bodies: (1) a sedimentary basin (now filled with quartzite) with $\Delta K = 1 \times 10^{-6}$ cgs units and $\Delta\rho = -0.15$ g cm^{-3} extending to 3–8 km depth, and (2) an intrusive body with $\Delta K = 0.01$ cgs units and $\Delta\rho = +0.01$ g cm^{-3} with its top at 3–8 km depth and its bottom at 35 km. This underlies an area bounded by 5.7 to 6.7°N and 19 to 23°E. Regan and Marsh noted that a disturbing aspect of the model is the high apparent susceptibility (of the order of 10^{-2} cgs) especially combined with the large volume of material considered.

A third possibility (suggested by a referee to this paper) is that the magnetic anomaly might be related to the iron formations (discussed later) which are found scattered over Central Africa.

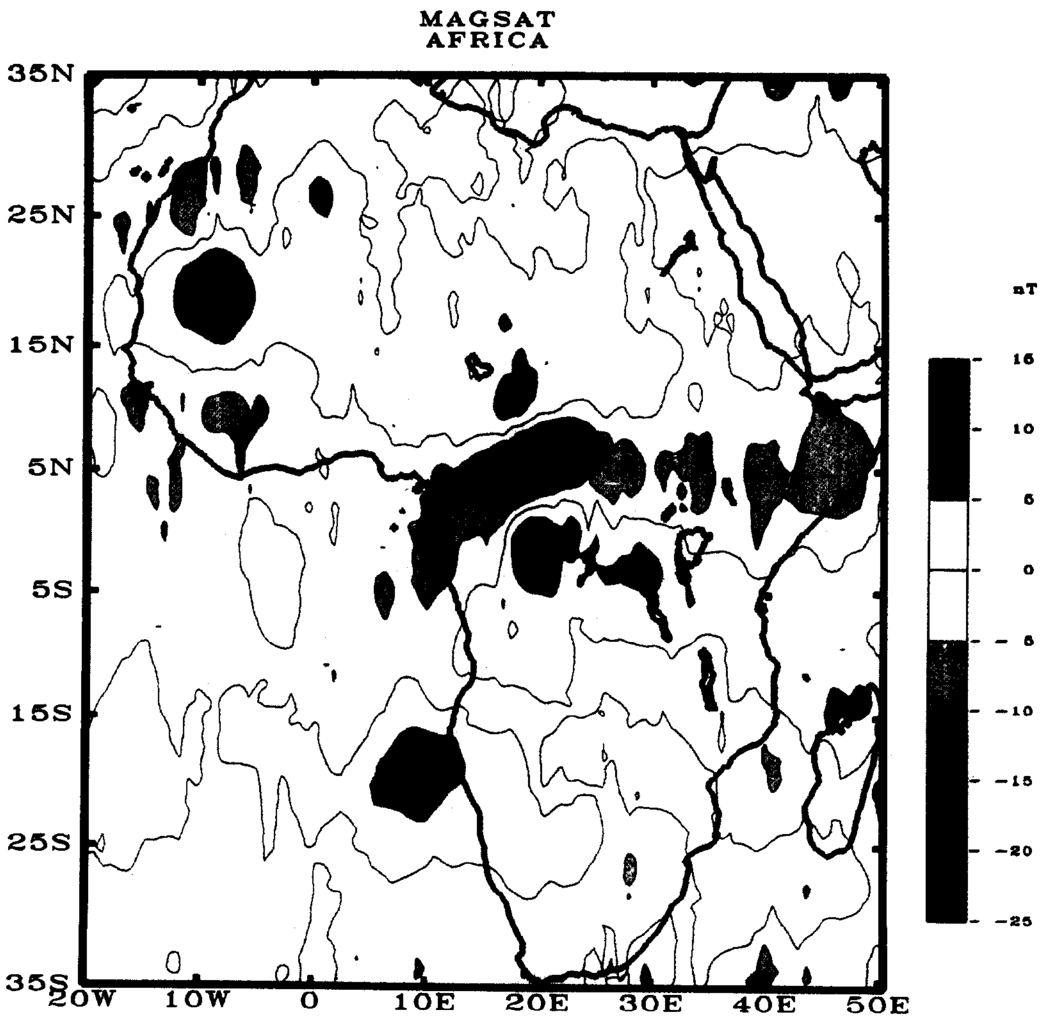

Fig. 1. Magsat total intensity magnetic anomaly map of Africa (contour interval 5 nT, altitude 375 km) showing the Bangui anomaly centred at 6°N, 18°E.

Here we explore the first possibility and present evidence that the large magnetic anomaly might in some way be related to an impact structure.

Evidence for a possible impact structure

The large size of the anomaly, both in area and amplitude, make it difficult to explain by any known geological feature. As noted, the most likely explanation is an enormous basic intrusion; apart from the unusually large size, the intensity of magnetization required to explain the large amplitude of the anomaly is much too high when compared with laboratory measurements on igneous rocks. It was decided therefore, to look for evidence for an extra-terrestrial cause.

Because of the difficulty of finding and assembling cloud-free Landsat coverage for such a large area of Central Africa, the 5-min topographic data base was examined—in particular, the north–south, west–east and vertical derivatives. All were found to reveal a double ring structure with the outer ring better defined than the inner (Girdler et al., 1989). An example is shown in Figure 2a with tracings of the double ring structure in Figure 2b. The outer ring measures about 810 km and the inner ring about 490 km. The

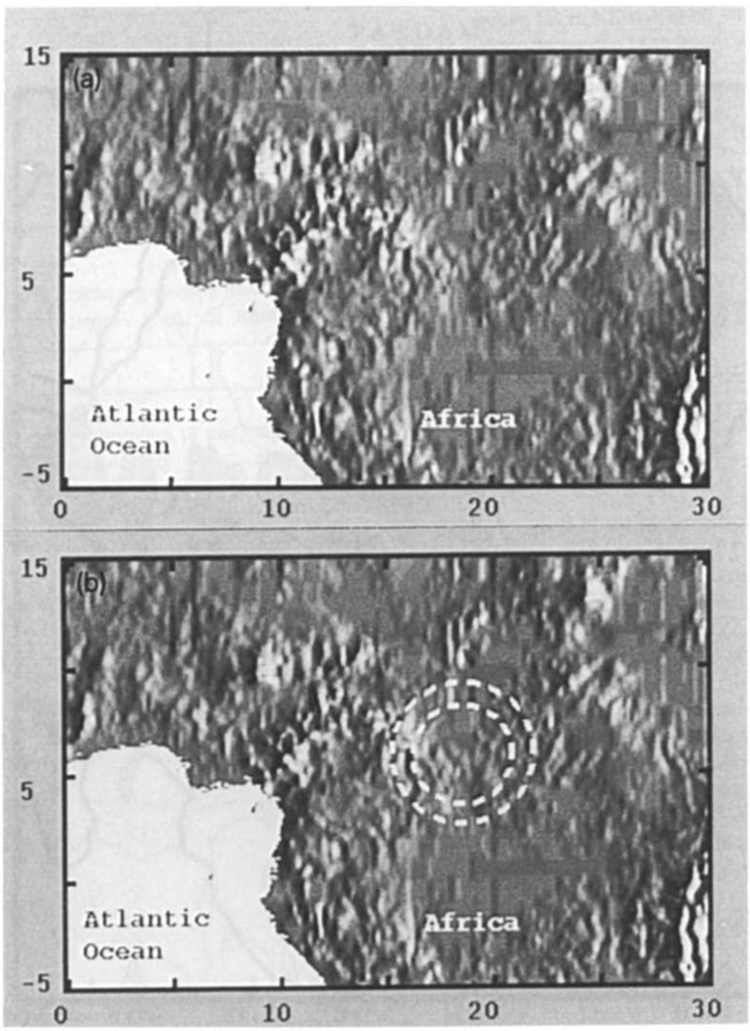

Fig. 2. (a) Image of the east gradient of topography centred on the Bangui magnetic anomaly. (b) The same as (a) but showing the ring structure highlighted.

centre of the ring structure is found to be at 6°N, 18.3°E, i.e., it shows a remarkable coincidence with the centre of the magnetic anomaly (cf., Table 1). To illustrate the correlation with the magnetic anomaly, the Magsat total field intensity anomaly is superimposed on the shaded relief map in Figure 3. The accurate location of the double ring structure may be obtained by comparing with Figure 2b.

In addition to the correlation with the magnetic anomaly, the ring structure also correlates with the negative Bouguer gravity anomaly. Figure 4 shows the ring structure outlined on the Bouguer gravity anomaly map from Regan and Marsh (1982). This shows the most intense negative area to be centred near 6°N, 19°E, i.e., close to the centre of the ring structure. The anomalies are seen to form part of a circle over the north

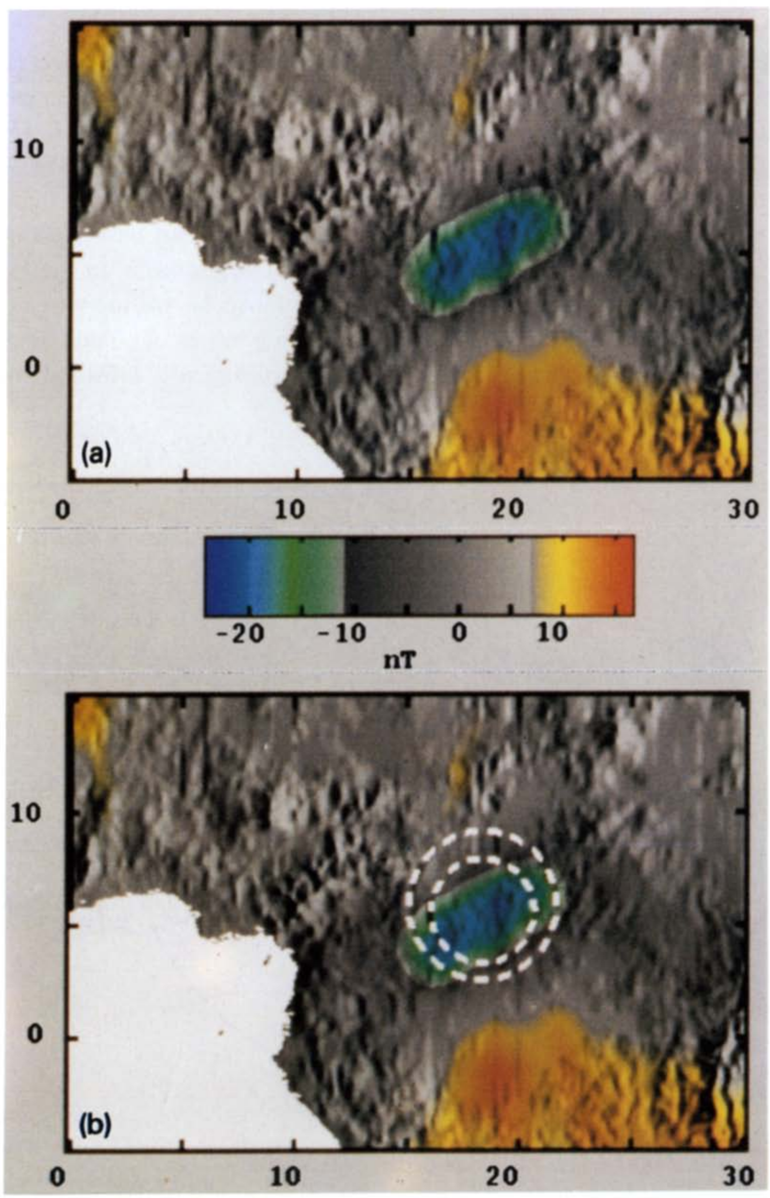

Fig. 3. (a) The Bangui Magsat anomaly superimposed on the topographic image of Figure 2a. (b) The Bangui Magsat anomaly superimposed on the topographic image of Figure 2a with the ring structure highlighted.

and west. A gravity study of a much larger area extending over Zaire and Cameroon is required for a thorough interpretation of the gravity anomaly and ring structure.

Sufficient data are available to reveal close correlations for the ring structure, satellite magnetic anomaly and negative Bouguer gravity anomaly. The three coincide remarkably, strongly suggesting a common cause. Here we concentrate on the interpretation of the magnetic anomaly.

A new look at the geology

A simplified geological map of the region based on Carte Géologique de la République Centrafricaine (Mestraud, 1964) and Regan and Marsh (1982) is shown in Figure 5. Virtually the whole area is Precambrian shield exposed on high ground (about 550 m) between the Chad and Congo (Zaire) basins. The centre of the magnetic anomaly is close to the ancient Oubangui Basin which is one of a cluster of small Precambrian basins. The early Precambrian geology gives the impression of a series of small basins within a very large basin with a high in the middle. Such a conglomeration of basins is typical of a large impact structure (S.R. Taylor, pers. commun., 1989). When the double ring structure identified in Figure 2 is transferred to the geological map (Fig. 5) the relationship is very apparent.

The oldest rocks form the Basal Complex and are early Precambrian; these make up 75% of the Precambrian exposures and are mostly migmatites, charnockites, metadiabases and metasedimentary rocks. Charnockites are thought to represent the lower crust; here they occur near the centre of the ring structure (Fig. 5) and could have been raised in the central uplift associated with large impact structures. Overlying the Basal Complex are middle Precambrian metasedimentary rocks which become increasingly siliceous; these fill the small basins which all form part of the much larger basin. In the Lobaye Basin in the south, the rocks are mostly quartzitic sandstones containing lenses of conglomerate and shale. The basin deposits are intruded by 550-My-old dia-

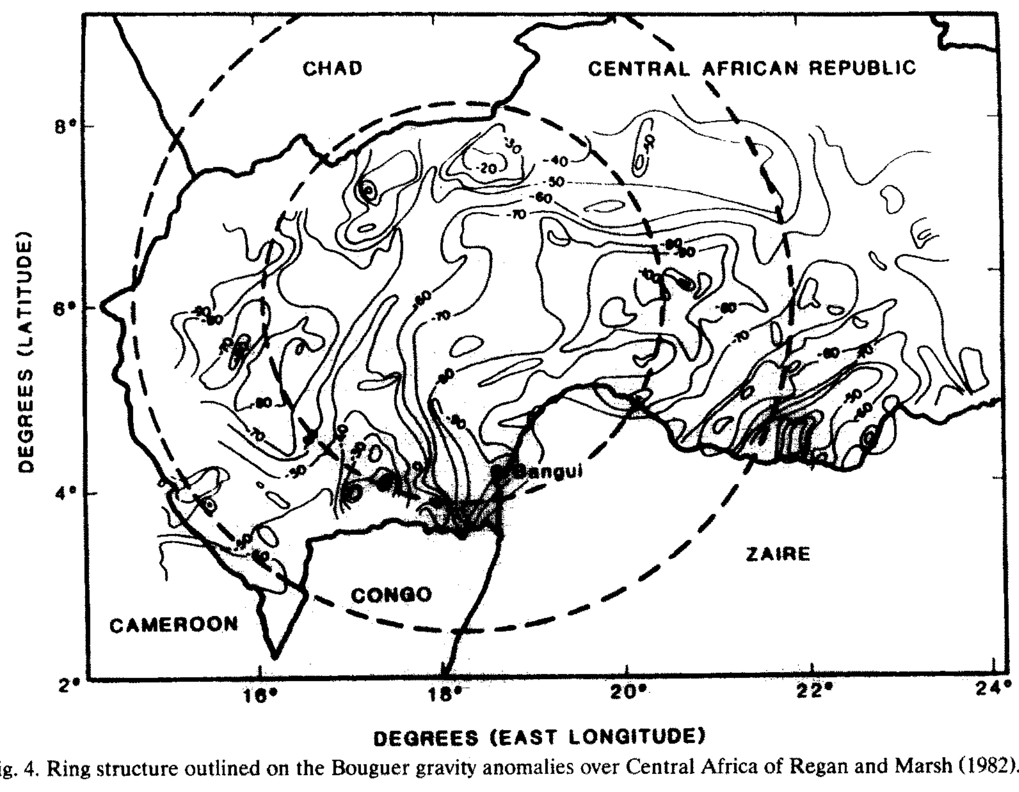

Fig. 4. Ring structure outlined on the Bouguer gravity anomalies over Central Africa of Regan and Marsh (1982).

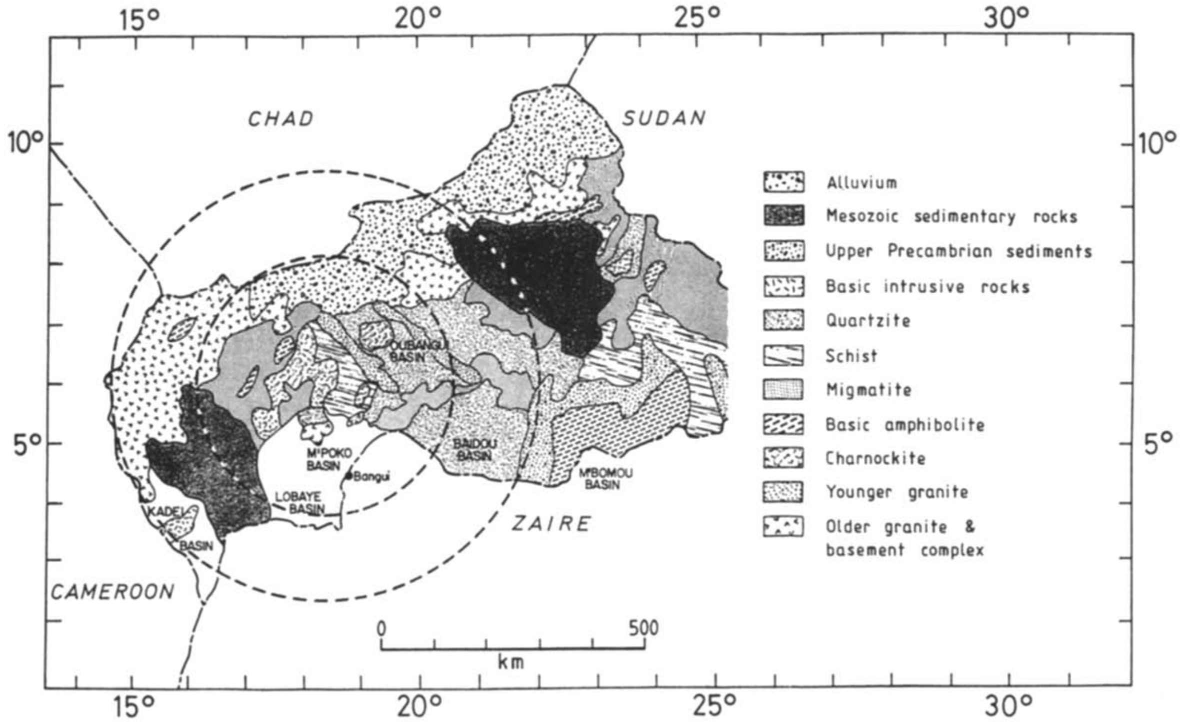

Fig. 5. Simplified geological map of the Central African Republic with the ring structure from Figure 2 superimposed.

base and granitic rocks. These intrusions cut all the units of the basin and are mostly granite with some more mafic rocks within these bodies.

In northernmost Zaire, the Bando granites dip north under the metamorphosed sedimentary rocks of the southern basins (Lobaye, M'Poko, and Baidou). The occurrence of extensive migmatites and high-grade metamorphic rocks at 6°N may indicate the northern limit of these basins and shallowing of the regional of the regional basin—this is about the centre of the ring structure. To the north, the quartzite formations begin again, marking the beginning of the Oubangui Basin which continues north for 150 km. The largest part of the magnetic anomaly coincides with the migmatites (6°N).

The aeromagnetic anomaly (Project Magnet) is essentially a high-amplitude, long-wavelength anomaly showing virtually no high-frequency content as seen on other profiles over Africa. This caused Green to argue the source must be highly magnetic, deep seated and extensive and therefore it was not surprising that the causative body is seemingly unrelated to the surface geology of metamorphic and sedimentary rocks. With the identification of a possible ring structure, it seems likely that both the magnetic anomaly and geological features are in some way related to a very large impact in the early Precambrian, i.e., in the early history of the Earth.

Three aspects of the possible impact structure are somewhat surprising: first, its size, secondly, its antiquity, and thirdly, the fact that it has survived as an erosional remnant for so long.

If the identification is correct, the large diameter (> 800 km) implies that the Earth was hit by a very large body creating by far the largest impact feature found so far. The diameter of the impactor was probably of the order of 80 km and could have been as large as 200 km (estimates can vary up to a factor of three depending on the scaling laws used; Melosh, 1989). In listings of possible impact features, the largest known is at Sudbury, Ontario (46.6°N, 81.2°W) with original structural rim diameter 150–200 km and age 1850 ± 150 My (Grieve, 1987; Grieve et al., 1991). The oldest known in Africa is the Vredefort ring structure (27°S, 27.5°E) with diameter about 136 km and age 1970 ± 100 My (Grieve et al., 1990). This also has a satellite magnetic anomaly (Fig. 1) but much smaller.

The suggested age (early Precambrian) is in accord with its great size. Grieve (1987) based on the early lunar record, notes that there should have been more than 100 impact structures with diameters of the order of 1000 km on Earth and that large planetesimals of the order of 50 km diameter were hitting the Earth in the early Precambrian.

The fact that a double ring structure is just discernible by processing the topographic 5-minute data base and that it has survived since the early Precambrian, is perhaps the most surprising aspect. This is probably due to its very great size and the fact that Africa has been a continent since the early Precambrian, being an

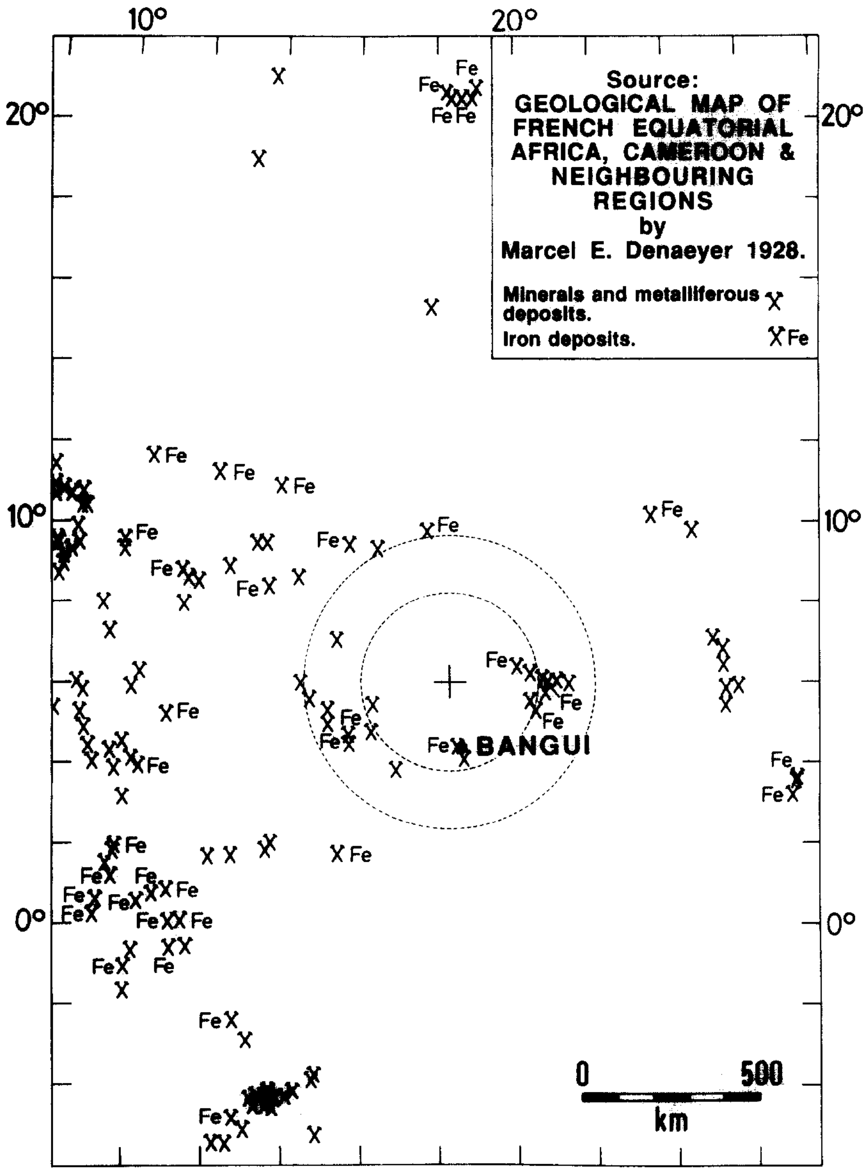

Fig. 6. Map showing the distribution of minerals and metalliferous deposits including iron together with the circular structure shown in Figure 2.

assemblage of cratons. During much of its history, Africa has been a land area. The huge impact must have excavated a very large crater. The depth of large complex craters is relatively shallow in comparison to their diameters (D). Grieve et al. (1981) estimate the maximum depth of excavation to be approximately $0.05D$ implying this crater could have been up to 40 km deep although most depth formulae give average estimates considerably less than this. Assuming the lithosphere to have a similar thickness to that of today, it is thus unlikely the impact would have given rise to a basic intrusion (i.e., consistent with the absence of any positive Bouguer gravity anomaly). The crater eventually became a series of sedimentary basins filled with various sediments which became metamorphosed through time producing the quartzites, migmatites, etc. mapped today (Fig. 5). These would erode differentially with respect to the older granite and basement complex and perhaps it is not so surprising that it is still possible to discern the crater remnant.

Since 1925, "carbons" have been mined in the Central African Republic. These are polycrystalline diamonds closely resembling the carbonados of Brazil (Trueb and de Wys, 1971). They are mined in two areas about 600 km apart, around Berberati (SW Ubangi) and around Ouadda (NE Ubangi). The diamonds are known from mineral associations to be crustal and not mantle in origin. Further, no kimberlite pipes or kimberlite mineral associations have ever been found in central Africa despite widespread prospecting and geological surveying. Smith and Dawson (1985) suggest these carbonados can be explained by impact metamorphism of crustal rocks containing organic carbon or a graphite derivative, including those of the Archaean and Proterozoic eras. This is supported by the presence of diamond-lonsdaleite-graphite-carbine in impact breccias of the Popigai impact crater, Siberia and the Ries impact crater, Germany.

Lastly, mention should be made of the widespread occurrence of iron through this part of Africa. In the Central African Republic, there is the Precambrian banded-iron formation which consists mostly of coarse, recrystallised chert grains and finer grains of magnetite and hematite, all intensely metamorphosed (Marsh, 1977). These banded-iron formations occur solely in Precambrian terrains and are usually 2200 million years old (Goldich, 1973). They are almost universally found in close association with thick sequences of quartzites but apparently their origin is enigmatic. The Central African Republic outcrops tend to occur around and beyond the outer ring of the possible impact structure (Fig. 6).

Iron deposits are also found over a very much larger area. These are shown in Figure 6 which is traced from the geological map of French Equatorial Africa, Cameroon and neighbouring regions compiled by Denaeyer (1928); also shown is the double ring structure traced from Figure 2. The map is useful as it depicts locations of mineral deposits. Unfortunately, these are mostly undifferentiated but where they are shown to be iron, they are annotated as such in Figure 6. The range of deposits recorded in the key include a whole range of heavy metals. The large number of iron deposits and heavy metals throughout the region suggest that the impactor causing the ring structure, might have been a large iron meteorite rather than a chondrite. The meteorite collision will have caused a huge explosion with relics extending for considerable distances from the resulting crater. The iron deposits will, of course, have been re-worked many times over the thousands of millions of years of geological history since the explosion.

The generally accepted scenario for impact structures (Melosh, 1989) is that the high-velocity projectile causing the structure vaporises completely on impact and the resulting vapour plume distributes material over a very wide area. Apparently, relics of the impactor are not usual in the melt glasses within the crater (H.J. Melosh, pers. commun., 1990) and it is very unlikely that there would be a large iron deposit at depth resulting from the impactor. It is therefore necessary to look for other causes of the large magnetic anomaly.

Possible causes of the Bangui magnetic anomaly due to impact and shock

The remarkable correlation of the locations of the large magnetic anomaly and double ring structure strongly suggests the magnetic anomaly is related to an impact event which from the regional geology must have been in the early Precambrian. This is plausible in view of: (1) shock remanent magnetization experiments; (2) palaeomagnetic studies of known impact structures; and (3) ground and air magnetic anomalies observed over known impact structures.

(1) Hide (1972) pointed out that the magnetic effects of high-velocity meteoroid impacts might not be negligible. Shock waves followed by rarefaction waves would spread from the area of impact first demagnetising any material shock-heated above the Curie temperature and then, as the material cools rapidly during the passage of the rarefaction wave, remagnetising the material determined by the background ambient field B. The main source of B would be the pulse of electric current generated by magneto-hydrodynamic interaction between the electrically conducting ejecta from the explosion and in this case the early Precambrian magnetic field of the Earth.

Laboratory investigations of rocks subjected to stress show that a remanent magnetism can be acquired in the presence of a weak external field (e.g., Shapiro and Ivanov, 1966; Nagata, 1971; Cisowski et al., 1973; Pohl et al., 1975). Cisowski and Fuller (1978) confirmed that shock pressures of tens of kilobars are sufficient to affect the remanent magnetism of terrestrial materials. These showed that the principal effects of impact are the demagnetisation of existing remanence followed by acquisition of an additional component related to the ambient field at the time of impact. For larger shocks of hundreds of kilobars, the transient and residual temperatures are high enough such that the acquired remanence is transitional to thermal remanence. Further, Cisowski and Fuller (1983) show that the stability of remanence is greater for higher pressure events. Thus, it is likely that shock remanence associated with a large impact can survive a long geologic history.

More recently, Crawford and Schultz (1988) and Crawford et al. (1989) have reported on laboratory hypervelocity impact experiments. These demonstrated that macroscopic hypervelocity impacts of 4.5 to 6 km/s can generate up to 2500 nT intensity magnetic fields in low ambient field environments. The magnetisation produced depends on the strength of the ambient field, the impact angle, the impact velocity and the material properties of both target and impactor.

The experiments suggest that the direction of shock remanent magnetisation (SRM) is parallel to the external field at the time of shock and the hardness and intensity of the SRM increase with shock pressure. Thus, for a large impact such as might have occurred at Bangui, shock remanent magnetisation would be very important. Presumably, the melt area near the centre of the impact will acquire a thermal remanent magnetisation (TRM) and the surrounding area a shock remanent magnetisation depending on the above factors. Both will make significant contributions to the size and magnetic intensity of any body proposed to model the satellite magnetic anomaly.

(2) Some early palaeomagnetic field work (Hargraves and Perkins, 1969) also suggested that shock might affect the remanent magnetism of rocks; in particular, studies at the Nevada nuclear test site showed that the natural remanent magnetisation (NRM) of the Rainier tuff from around the site of the nuclear explosion has direction of stable remanent magnetisation very close to that of the local magnetic field of the Earth, suggesting remagnetisation due to shock.

Palaeomagnetic studies have been made of several known impact structures including Manicouagan, Quebec (Larochelle and Currie, 1967; Robertson, 1967), Mistastan Lake, Labrador (Currie and Larochelle, 1969) and the Slate Islands impact site in northern Lake Superior (Halls, 1975, 1979). The last is in 1100 My Keweenawan rock and has an estimated diameter of about 30 km; the impact is thought to have occurred less than 350 My ago. Halls showed that a component of remanence is confined to rocks having experienced intense shock (50 to >1000 kbar) based on shatter cone development and the presence of planar features in quartz and felspar and thus concluded this must be shock remanence (SRM). He was also able to show that this SRM component must have been acquired virtually instantaneously in terms of normal geological processes as a combined palaeomagnetic-shatter cone analysis suggests that it was acquired during the very short time interval between the moment of impact and the formation of the central uplift. Further, the SRM has very small dispersion confirming it was acquired almost instantaneously during the 2–3 second passage of the shock wave following impact. The extent of magnetic resetting is found to decrease with distance from the centre of the impact site. Studies were also made of intrusive breccias which were injected into pre-existing joints or newly formed cracks. These also have a secondary component of magnetisation identified as partial thermal remanence (PTRM) or of thermochemical origin (TCRM). The breccia having been heated through friction during transport and by energy transfer from the impacting body begins to cool acquiring a TRM, PTRM and TCRM in the direction of the ambient field after the host rocks with their sudden shock remanence (SRM) were rotated in the formation of the central uplift.

These studies confirm the presence of several components of magnetisation at the impact site, i.e., TRM, PTRM, SRM, TCRM, all of which depend on the size of the impact and contribute to the cause of the magnetic anomaly. The importance of many of these has been discussed by Wasilewski (1973).

(3) There have been several magnetic surveys of known impact structures; examples include Manicouagan, Quebec (Coles and Clark, 1978), Lake St Martin, Manitoba (Coles and Clark, 1982), Haughton, Devon Island in the Canadian Arctic Archipelago (Pohl et al., 1988) and Vredefort, South Africa (Antoine et al., 1990). All have impressive magnetic anomalies.

The Manicouagan structure has a central positive anomaly of 2000 nT (flight height 300 m) which was interpreted as being due to a tabular body of variable thickness between 1 and 3 km depth.

The Lake St Martin structure has a diameter about 24 km and age 225 ± 40 My. A ground magnetometer survey found an intense negative anomaly of -1000 nT over the centre of the structure superimposed on a broader negative anomaly. Coles and Clark (1978) interpret this as being due to shocked gneiss, the direction of remanence being consistent with the Permo–Triassic age. The stable remanence is mainly CRM in red hematite resulting from post-impact extensive alteration of mafic silicates in shocked gneiss of the central uplift. The magnetic anomalies have been modelled using near surface prisms with reverse Permo–Triassic remanent magnetisation.

The Haughton impact structure with diameter 21 km and age 21.5 My has a local magnetic anomaly of 700 nT which coincides with a negative Bouguer anomaly of -12 mGal. The highest remanent magnetisation (> 1 A m^{-1}) is found in shocked gneissic samples which have very low magnetic susceptibility and Konigsberger ratios of up to 50. The magnetic anomaly has been modelled with a near surface body of highly shocked rock with magnetic intensity 1.3 A m^{-1} and nearly vertical SRM, i.e., it was located near the pole at the time of impact (Pohl et al., 1988).

The total field magnetic anomalies over the Vredefort structure, southern Africa have been subjected to image processing revealing a central negative anomaly of up to -500 nT within a surrounding ring about 50 km in diameter with anomalies also reaching -500 nT. In between the anomalies are zero or slightly positive (Antoine et al., 1990). As previously mentioned the overall anomaly can be seen on the satellite magnetic anomaly map (Fig. 1).

In the light of these examples, it seems reasonable that the Bangui magnetic anomaly might also be explained as being due to an impact structure, the main difference being of scale, Bangui being many times larger than any previously studied impact structure. Further, if an impact origin is accepted it becomes relatively easy to explain the large amplitude of the satellite magnetic anomaly which can be modelled with a body with thermal remanence (TRM), partial thermal remanence (PTRM), shock remanence (SRM), thermo-chemical remanence (TCRM) and sometimes chemical remanence (CRM), all contributing to the total magnetic intensity.

A simple model for the Bangui magnetic anomaly

Taking into account the above scenario of magnetic fields produced by impact and the crustal magnetisations found at other impact sites, a simple model for the Bangui anomaly is presented in Figure 7. The main difficulty lies in deciding a realistic shape for the causative body. Wasilewski (1973) gave a picture of a hemispherical zone beneath the impact but this seems more appropriate for small impacts. For large impacts, the crater tends to be very large in area in comparison to its depth suggesting the explosion is most effective horizontally. In the model presented, a circular disc is used, the disc being placed beneath the sedimentary basins used by Regan and Marsh (1982) to explain the negative Bouguer gravity anomaly. The negative Bouguer gravity anomaly is now considered to be due to a combination of the sedimentary basins within the impact structure and the lowered rock densities due to impact-related fracturing in the old crater floor and surrounds. Thus the top of the body is placed at 3 km, i.e., the average depth used by Regan and Marsh (1982). The diameter used is 800 km, i.e., the size of the identified structure and the thickness 4.5 km, but these are arbitrary as it is not known how much material is affected by the thermal, partial thermal remagnetisation, shock magnetisation and chemical magnetisation. Undoubtedly, for an impact of this size, it must be a very large volume. At this low magnetic latitude, the computed anomaly exhibits a large negative over the disc with positive lobes to the north and south, the relative magnitudes of these depending on the direction of the total magnetisation vector. Assuming uniform magnetisation, such a body requires a total intensity of magnetisation of 10 A m^{-1} and normal direction of magnetisation with $D = $ N 18°W, $I = +25°$ to fit the amplitude and shape of the satellite magnetic anomaly at height 375 km. The direction is significantly different from the present dipole field $D = 0$, $I = +12°$ and inducing field $D = $ N 3°W, $I = -12°$, as might be expected for a body with stable remanence acquired during the early Precambrian. It should be noted that the amplitude and shape of the anomaly are most sensitive to the magnitude and direction of magnetisation, details of the shape of the body making little difference. In actuality, the body being magnetised in many different ways is unlikely to have uniform remanence.

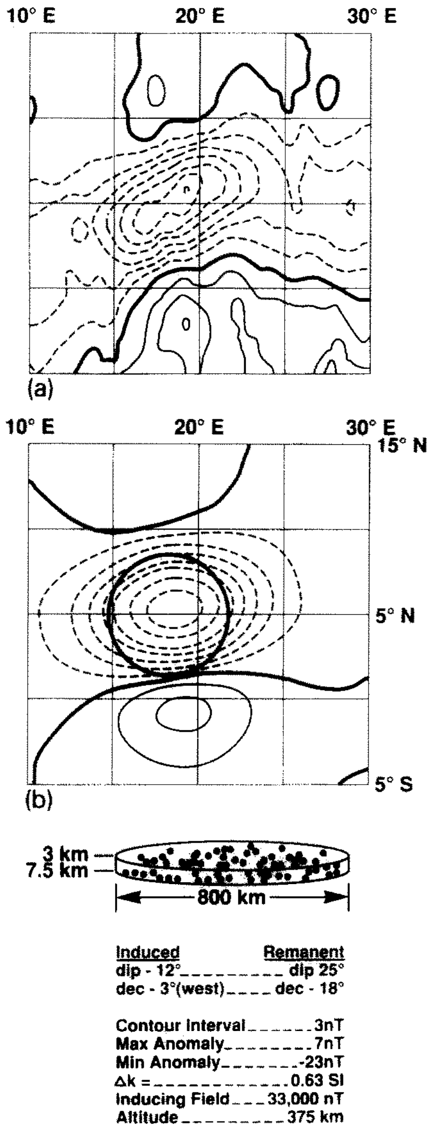

Fig. 7. (a) The observed Magsat anomaly with the zero contour shown bold, the positive anomalies solid and the negative anomalies dashed. (b) Simple disk model for the Bangui magnetic anomaly at Magsat altitude.

The interpretation requires confirmation especially by field studies but unfortunately the region affected by the proposed impact is logistically difficult, covering several countries in Central Africa. An examination of a selection of thin sections by Bevan French of rocks sampled within 350 km of the city of Bangui, Central African Republic (Marsh, 1977) has been made. This study failed to find any effects of shock metamorphism or even deformation by conventional standards for Precambrian metamorphic rocks. However, the samples were metamorphosed to very high grade (amphibolites to granulites) and "...it is probable that any petrographic shock effects present in the Bangui rocks before metamorphism would have been destroyed" (B. French, written commun., 1990). Smith and Dawson (1985) also suggest that high-pressure coesite and stishovite might invert to quartz over geological time in which case it would be important to check for textural evidence of inversion structures in the quartz grains. Further field work should therefore seek megascopic shock features (e.g., shatter cones).

Once the concept is accepted that some of the continental satellite magnetic anomalies might be related to impact features, a whole new fascinating field of study is opened. For example, the large satellite magnetic anomaly over southern Australia might be related to the well documented Acraman impact. Several such anomalies are under investigation.

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