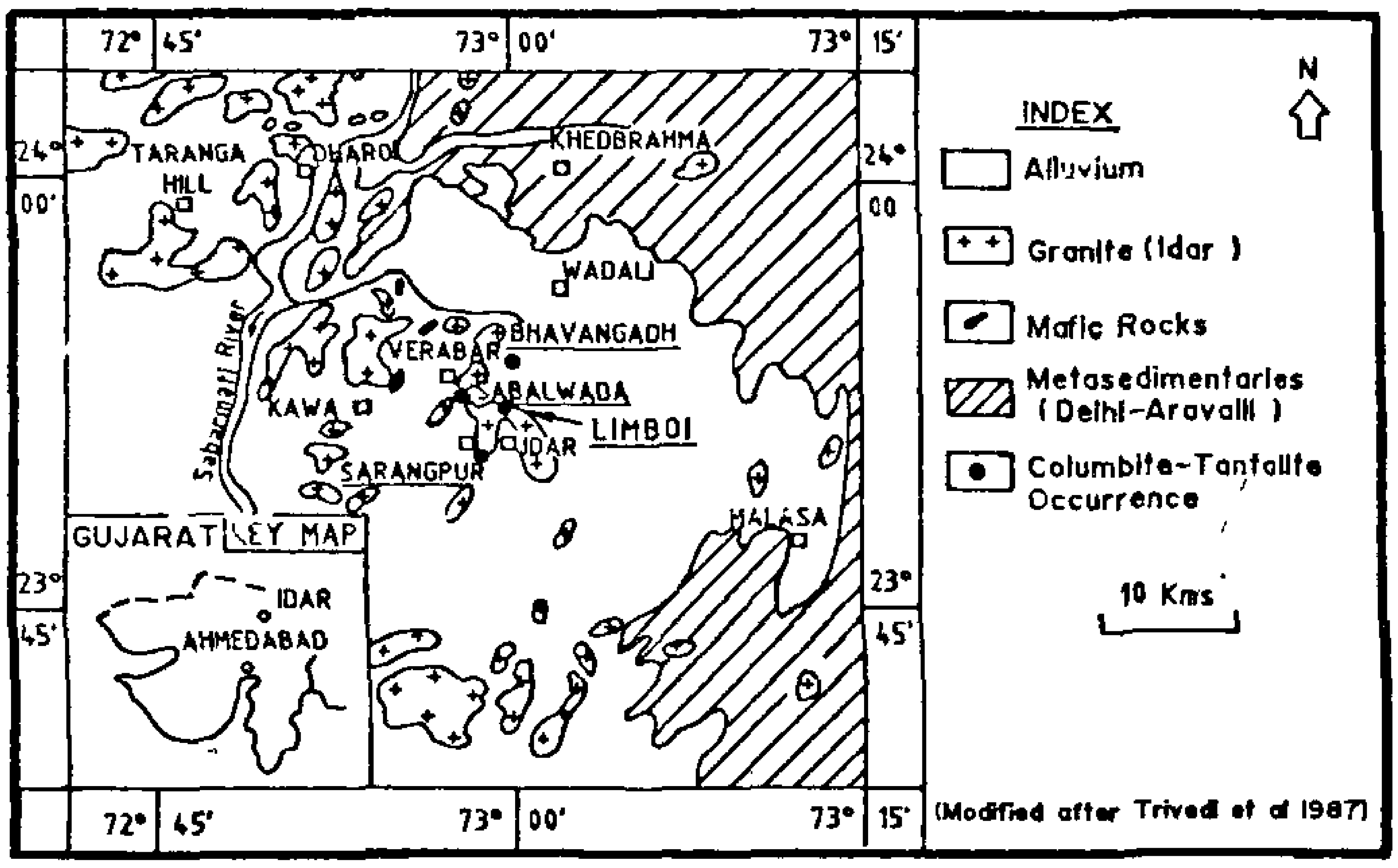


Figure 2. Geological map of Idar Area, North Gujarat, showing columbite–tantalite occurrences

The presence of columbite–tantalite-bearing pegmatites around Limboi and granitic terrain occupying about 1200 km$^2$ have opened up vast area for exploration of rare metals and rare earths. Follow-up investigations in the area around Verabar, Kawa, Dharoi, Nadri, Nawawas, in the Sabarkantha district of Gujarat and also in the adjoining Banaskantha district of Gujarat and Sirohi district of southwestern Rajasthan are likely to be rewarding, as fertile granites are present in the area.

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RESEARCH NEWS

# Discovery of the new radiation belt of the earth

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The discovery of the new – the third-radiation belt of the earth has followed from the results obtained with the help of earth-orbiting satellites[1]. This discovery was made in three stages. The first evidence came in a striking manner in the Indian cosmic-ray experiment[2,3] in the SKYLAB-III mission of NASA during 1973–74 Further evidence was obtained from the results of the COSMOS satellites[4] of USSR flown in 1985–88. Finally, the confirmation and identification of the new belt was made from the results of the SAMPEX satellite[5] of NASA of USA in 1993.

Firstly, let us have a brief look at the two well-known radiation belts of the earth, the inner and outer belts discovered in 1958–59. These are also called Van Allen Belts after their discoverer, J. A. Van Allen of USA A number of satellite experiments were needed to understand their properties and origin. The inner belt consists of energetic charged particles, mostly protons (of energy ~ 10 to 100 MeV) and some electrons which are confined in a dough-nut shaped volume around the earth by the earth's magnetic field. The charged particles travel in spiralling paths around the magnetic field lines and they oscillate between the north and south hemispheres. At the same time they circle around the earth, forming a belt-like structure. The centre of the inner belt is located at about 3,600 km altitude where intensity of fast protons is enormously high. Similarly, the outer belt, which is composed of mostly fast-moving electrons, extends from ~ 10,000 to 70,000 km altitude. It has extremely high intensity of fast electrons near its core at 20,000–30,000 km These trapped radiation belts present serious radiation hazards to man and instruments in these regions of space.

A new kind of cosmic rays were first seen in interplanetary space in experiments on Pioneer 10 and 11 and IMP-8 spacecrafts of USA in 1973–74 (refs. 6–8). These new components of cosmic rays, called anomalous cosmic rays, were first seen in near-earth space, inside the earth's magnetic field in the Indian cosmic-ray experiment[2,3] on the Skylab-III mission of NASA. The surprising result found in this experiment was that the measured intensity in the solid state track detectors in Skylab was at least 25 times higher than the calculated value from the data in interplanetary space. How could it be possible?

It was proposed by the Indian group[3] that some of the anomalous cosmic-ray

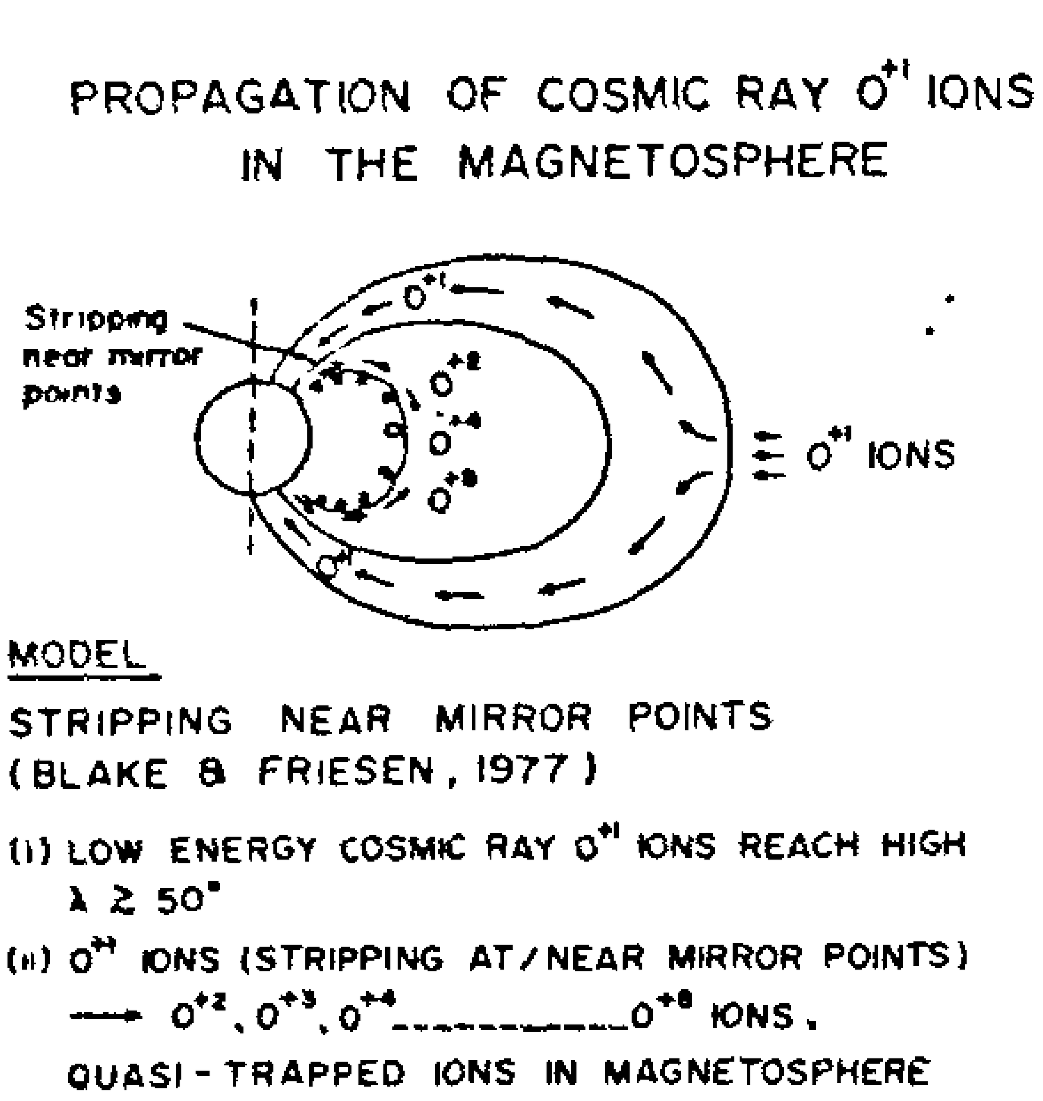


**Figure 1.** A sketch of the model of the origin of the newly-discovered radiation belt of the earth originating from the trapped anomalous cosmic ray particles, such as $O^{1+}$ (from ref. 3). For details see text.

particles were trapped in the earth's magnetic field and these trapped or quasi-trapped particles were responsible for the excess flux. The mechanism for trapping was also suggested[3] by the Indian group. This mechanism, which is discussed a little later, is now accepted as the model for the origin of the trapped anomalous cosmic rays. In the Skylab experiment it was, however, not possible to locate the position of the new trapped component, for which more detailed experimentation was necessary.

A few attempts were made in early 1980s on this problem, but without success. In 1985–88, the USSR group made several *COSMOS satellite flights with* solid state track detectors, in some of which they noted double-peaked angular *distributions of the oxygen ions of* anomalous cosmic rays[4]. These were interpreted as arising due to the presence of a trapped component. Thus the evidence for the trapped component became stronger.

In 1992–94, the Caltech and NASA groups of USA flew a sophisticated mass *spectrometer experiment in* a NASA satellite, SAMPEX, whose orbit was at a higher altitude of 670 km. It was a polar-orbiting satellite with orbital inclination of 82° to the equator. The results from this experiment yielded the new evidence of the trapped anomalous cosmic rays[5], which confirmed earlier observations. It showed a distinct component which was due to trapped heavy ions of anomalous cosmic rays (ACR) and was composed mainly of oxygen ions of about 10–50 MeV/N. They located the new radiation belt of trapped ACR at a distance of about 6400 km above the equator. The trapped particles are confined in a torus-like region around the earth's equatorial region. From this volume a small fraction of trapped particles leaks out in high altitude regions of the upper atmosphere above the South Atlantic ocean region and these were detected by the earth-orbiting satellites when they passed through this region.

The mechanism for the formation of the trapped component of anomalous cosmic rays was proposed by the Indian group[3] and this is shown schematically in Figure 1, which is reproduced from the paper of Biswas and Durgaprasad[3]. In this model it is proposed that singly ionized ions of anomalous cosmic rays, such as $O^{1+}$, enter the geomagnetic field at high latitudes, say ≥ 50°. Here a fraction of these suffer electron stripping process in the upper atmosphere near their mirror points according to Blake–Freisen mechanism[9]. The stripped ions having lower magnetic rigidities (i.e. momentum/effective charge) are trapped, forming the trapped component of anomalous cosmic rays. One may note that in this picture the ACR ions should be singly ionized; several experiments have determined that ACR ions of O, N, Ne are singly ionized[10]. The trapped heavy ions of ACR are stored in the belt for periods ranging from less than a day to about one year, depending on the ionization loss in the thin rarified regions of space where gas densities range from about $10^3$ to $10^6$ atoms/cm$^3$.

One may ask about the scientific usefulness or otherwise of this new radiation belt. The new belt is of weak intensity and so does not present any additional radiation hazard compared to the high intensity Van Allen belts. This belt, however, provides a new advantage. It is now established that ACR particles originate from neutral atoms of nearby interstellar space[10]; therefore the new belt of trapped ACR particles brings to us a sample of interstellar matter in near-earth space Thus new properties of interstellar neutral matter, e.g. their isotopic composition, can be studied and new, important astrophysical knowledge may be obtained.

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