Research in Progress

The View from Tibet

India and China have been on a collision course for some time — not just ideologically as in recent years but quite literally, physically, for the past 200 million years. That's when, geologists now think, India broke off from Gondwanaland — the southern hemispheric supercontinent — and began drifting northward, finally slamming into Tibet about 40 million years ago. Last October, Professor of Geology and Geophysics Clarence R. Allen was chairman of a 10-man American delegation to Tibet, the first such group allowed into the region to observe the geological evidence of this collision, which created the Himalayan Mountains.

Unlike most mountain chains, the Himalayas, which are the world's highest mountains, sit squarely in the middle of a continent. It has been only in the last 20 years that a major revolution in geological concepts, plate tectonics, has enabled scientists to figure out what, Allen says, schoolchildren have long pointed out — that the Himalayas look like the folds of a tablecloth pushed forward between two fingers and bunched up at the corners.

Another geographic anomaly has also been known for many years — that two of India's major rivers, the Indus in the west and the Brahmaputra in the east, both rise in Tibet on the far side of the Himalayas, actually within a few miles of each other. Before flowing southward at opposite ends of the great range, they describe a broad linear zone characterized by a distinct belt of rocks. Allen wanted to find out what Chinese geologists had learned about these rocks and what the area might reveal in support of recent geological theories.

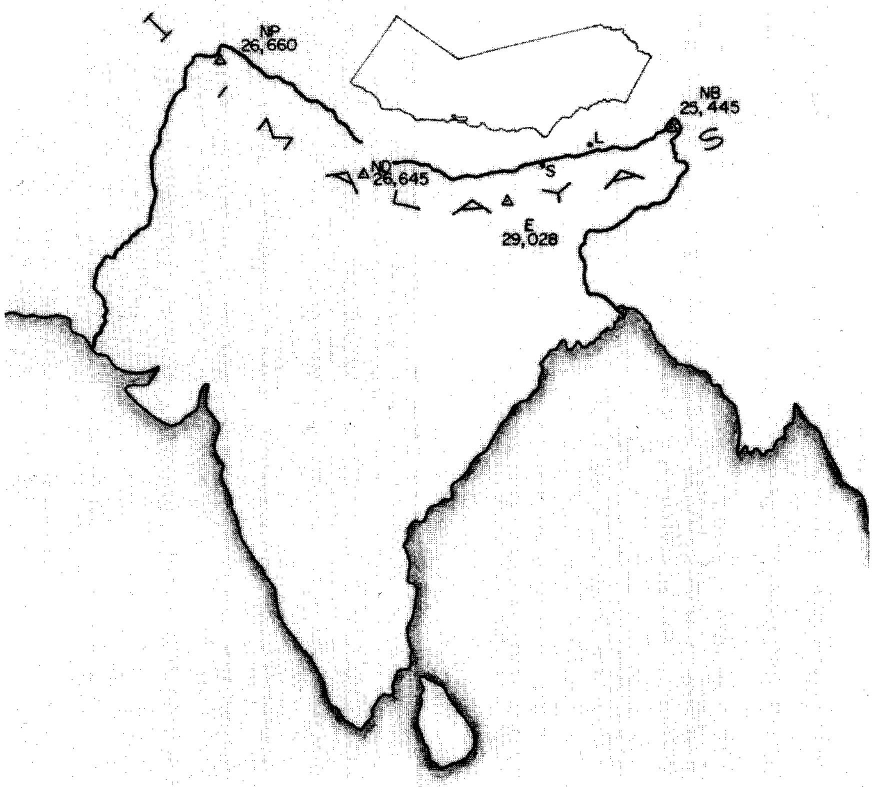
According to plate tectonics, molten rock is constantly flowing up from the earth's mantle along mid-ocean ridges; it solidifies and moves sideways away from the ridges until it is forced to dive, or subduct, under the relatively stable and rigid continental plates where it is reabsorbed into the mantle. This process can be traced by magnetic signals along the ocean floor, where the irregular flipping back and forth of the earth's polarity has left an important record, recognizable in distinct magnetic patterns in the newly formed crustal material. These characteristic magnetic stripes can be read like tree rings and allow geologists to reconstruct the history of the ocean floor.

Although the floor of the Indian Ocean is more complicated than, for example, that of the Atlantic, which has a single spreading ridge, India's northward path can be traced through these magnetic clues. They show that between 80 and 100 million years ago India was approaching the Asian continent; crust was subducting in a trench at what was then the Tibetan coast. But since a continental plate is too light to subduct (it rides like the froth on a wave), as the two continents neared each other, a lot of things began to happen. There is controversy over what actually did happen at the sub-crustal level, but Chinese observations of the rocks in the "suture zone" in southern Tibet substantiate the view that this is the primary line of impact.

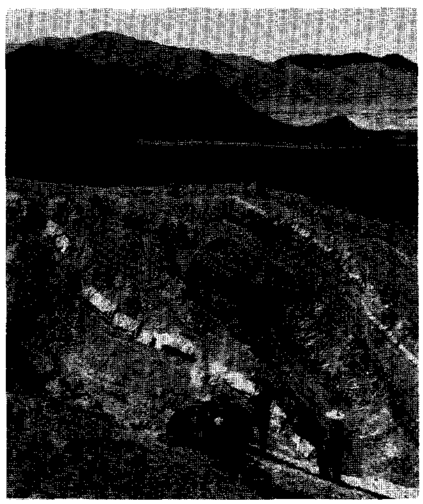
In addition to rocks more than 200 million years old, formed when India was still a part of Gondwanaland and now mangled and squeezed from impact, and granite in the Trans-Himalaya similar to that of California's Sierra Nevada, Allen observed ophiolites — rocks unique to the ocean floor. Examples of these ophiolites in the suture zone were pillow lava, molten bubbles extruded from submarine volcanoes; red cherts, porcelain-like siliceous material characteristic of deposits on the deep ocean floor and datable by fossils; and harzburgite from the mantle itself, rich in iron and magnesium. The presence of this unique set of rocks makes geologists certain that this area, now 15,000 feet high on the inland side of a mountain range, was once the floor of the Indian Ocean, squeezed and uplifted in the collision.

Even after the last gap of ocean was closed when the Indian plate rammed into Tibet 40 million years ago, India did not stop moving. It has continued to advance another 1,500 kilometers, creating in its forward push the highest mountains in the world. But even if you could iron out all the folds in the Himalayas, you couldn't account for the entire distance. Allen and other geologists suggest that the crust in Tibet is so thick that it is capable of transmitting clear up to Mongolia stresses that otherwise would have accumulated along the suture zone. The major earthquakes along faults throughout China are a means of relieving these pressures, which are still building up.

Allen, who is known primarily for his earthquake expertise, hopes to return to China next year to study the Red River fault in Yunnan to try and gain a better understanding of these stresses. □



The Indus River (left) and the Brahmaputra (right) rise quite close to each other and flow along the suture zone where India joined Asia 40 million years ago, piling up the Himalayan Mountains from the force of the collision. Some of the higher peakes are indicated with their elevations; the American geologists traveled between Lhasa (L) and Shigatse (S). California has not broken off North America and migrated to Tibet but is placed on the map for scale.



Folded sedimentary rocks near Shigatse provide evidence of the continental collision of India with Asia.

These pillow-shaped rocks were once a part of the Indian Ocean floor where they formed from cooling lava.

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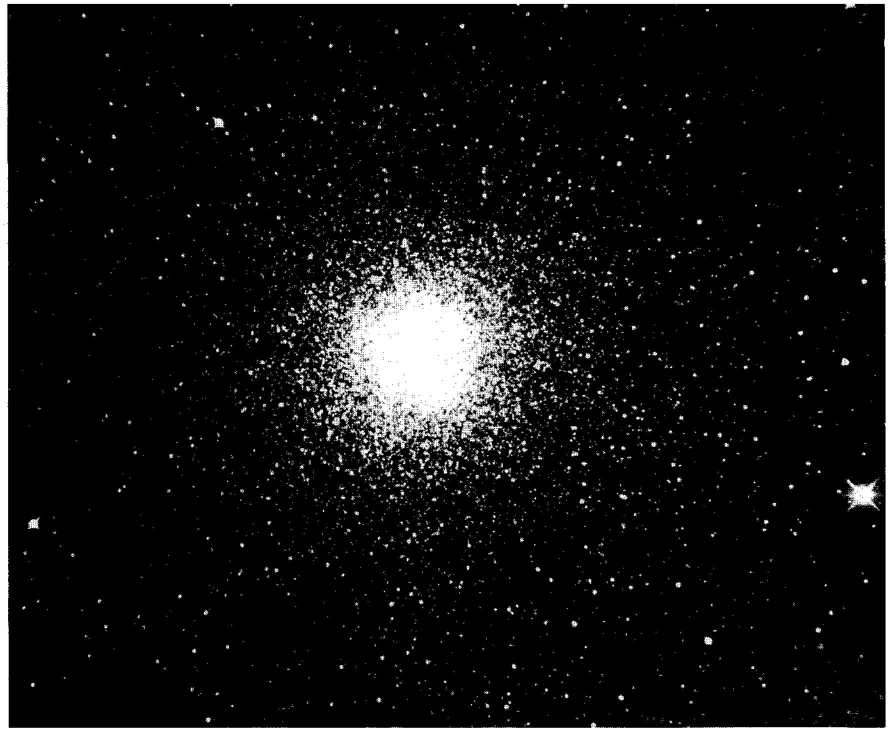
Galactic Genesis



Globular cluster M3, an intermediate distance out in the Milky Way's halo, was photographed in 1910 at Mount Wilson. Clusters nearer the center of the galaxy are more difficult to distinguish from the field of background stars, and only with recent advances in technology have the spectra of their stars been analyzed, overturning theories that these had a considerably greater abundance of heavy elements and were younger.

Most of the billions of stars in the Milky Way are concentrated in a flat "pancake" or disk that is thought to have been formed by the collapse of a spherical cloud of gas. The disk is surrounded by a spherical halo that extends out about 65,000 light years and that contains relatively few stars. Most of the stars in the halo are closely packed together in globular clusters of up to 100,000 stars each. The halo and its globular clusters, of which about 150 are known to exist, are considered remnants of the primordial gaseous sphere. Astronomers believe the stars in globular clusters to be the oldest in our galaxy and have looked to them for clues to its chemical history. Those globular clusters concentrated near the center of the galaxy have been thought to have condensed out of the gas further along in the collapsing process — hence to be somewhat younger — than those out in the halo.

The age of these halo stars can be estimated by the concentrations of elements heavier than hydrogen and helium, which can be determined by analysis of their spectra. It had been generally believed by astronomers that the stars of the globular clusters near the center were richer in heavy metals than the clusters scattered in the outer reaches of the halo, and Judith G. Cohen (Caltech PhD '71), associate professor of astronomy, undertook to find out if this were true.

The stars in globular clusters are very faint, and their spectra are difficult to measure. Astronomers have also been led astray in measurements of presumed metal-rich clusters near the galaxy center by field star contamination; that is, when you're looking at a globular cluster through the Milky Way disk, it's very difficult to differentiate a star that is a member of a globular cluster from the numerous stars in between us and the cluster. So it was not until about four years ago that improved observational techniques — a combination of big telescopes and modern electronics — made accurate spectral measurements of these faint stars possible.

Using these new spectroscopic techniques, Cohen discovered that the metallicity of M71, a globular cluster near the center of the galaxy, was much lower than previously estimated. Recent studies of another such cluster support this finding. Cohen, who has studied several other globular clusters, speculates that all the clusters near the galactic center will prove to be relatively metal-poor, a fact that will change and in many ways simplify the picture of the galaxy's history. The previous picture contained a contradiction — there was a sizable overlap in assumed metal abundance of the close-in globular clusters and a large number of stars in the Milky Way disk, and that implied that they were about the same age. If the formation of globular clusters indeed preceded the final stages of collapse of the gassy sphere into a disk, there should be no overlap in metal concentrations or age. Cohen's picture does not have this overlap. She concludes that there is no correlation between the metallicity of globular clusters and their position in the halo; she believes they formed independently of one another within a relatively short period of time and with widely varying metallicities. The stars in the disk formed after all the globular clusters did, but those disk stars that formed first were equal in metallicity to the most metal-rich globulars.

While appearing to resolve one puzzle, her investigations also present a new one. It has been predicted that the ratios of the different heavy metals to each other would be significantly greater in the older stars. Cohen's observations show no such change in these ratios.

Besides globular clusters in our own galaxy she also studied some in Andromeda, a large spiral galaxy much like the Milky Way. Although the stars are so faint they cannot be studied individually, she believes from the integrated light of all the stars as a whole that Andromeda's globular clusters share the same range of metals, age, and mass distribution within the cluster as the ones in the Milky Way. She is planning observations of globular clusters in the Large and Small Magellanic Clouds, which are galaxies of a very different kind from ours in shape, size, and family of clusters associated with them. □