SPACE IMAGERY AND SOME GEOMORPHOLOGICAL PROBLEMS OF THE GUIANA SHIELD, S.A.

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Introduction

Like most academic geomorphologists, I know relatively little about planetary geomorphology, nor am I especially qualified to engage in constructive "megathink" about global geomorphology, though I have been guilty of some original considerations about the reality of ancient cyclic erosion surfaces in the global framework (Melhorn and Edgar, 1975).

For purposes of this workshop, I therefore will describe some ongoing involvement in regional geomorphologic research in South America. Because of association with LARS at Purdue University, there has been engagement, vicarious or advisory, in projects which led to Landsat 1-2 mapping of the natural resources of Bolivia (1:8,000,000 scale), and preparation of a geographic information system which mapped the general hydrology, geology, soils, and vegetation of Ecuador (1:4,000,000 scale). Currently we are involved more specifically in geological-geomorphological mapping of the Venezuelan portion of the Guiana Shield, and because of manuscript limitations only questions pertinent to this region are posed in the ensuing discussion.

The study of Venezuelan Guiana has evolved in the last few years from preliminary study of Landsat imagery (Fig. 1) into more localized and detailed geomorphologic analysis of the Roraima portion of the Guiana Shield, using a semi-controlled radar imagery mosaic (Fig. 2) and 4,000 black-and-white aerial photos, both available only at 1:250,000 scale. Gradually emerging is a geomorphological-geological map, at the same scale, intended for use in regional planning and economic development of a thinly populated, wild, inaccessible region of rich natural resource potential extremely important to a developing nation. As expected, each step forward has led to new questions about the geomorphic history and evolution of the region.

Regional Setting

Some geological background is prerequisite to questioning and analysis. The Guiana Shield is of subcontinental magnitude. It consists of ancient 3.6-3.8 b.y. old, intensively deformed and metamorphosed Archean rocks. Scattered across the Shield are remnant outliers of the Roraima Group, a sedimentary sequence as much as 3300 m thick that lies unconformably on the older basement; presumably the Roraima is of Proterozoic age on the basis of radiometric dates obtained on dolerite dikes and sills which crosscut the Roraima in part. Apparently the Roraima formerly was a great prism of intra-cratonic sediments nested on and within the broad, bowl-shaped older pre-Cambrian basin. However, long-term erosion has removed most of this cover, leaving outliers marked by a series of near-vertical scarps, and a series of magnificent step-like cuestas, whose dip slopes incline 4°-6° inward towards the center of the Proterozoic depobasin. Because of lithologic variations, sloping stripped surfaces abound and are the most striking landform element. Gansser (1954) suggested that the Roraima formerly covered as much as 475,000 km^2 and extended from Surinam to the Sierra Macarena in Colombia. Present

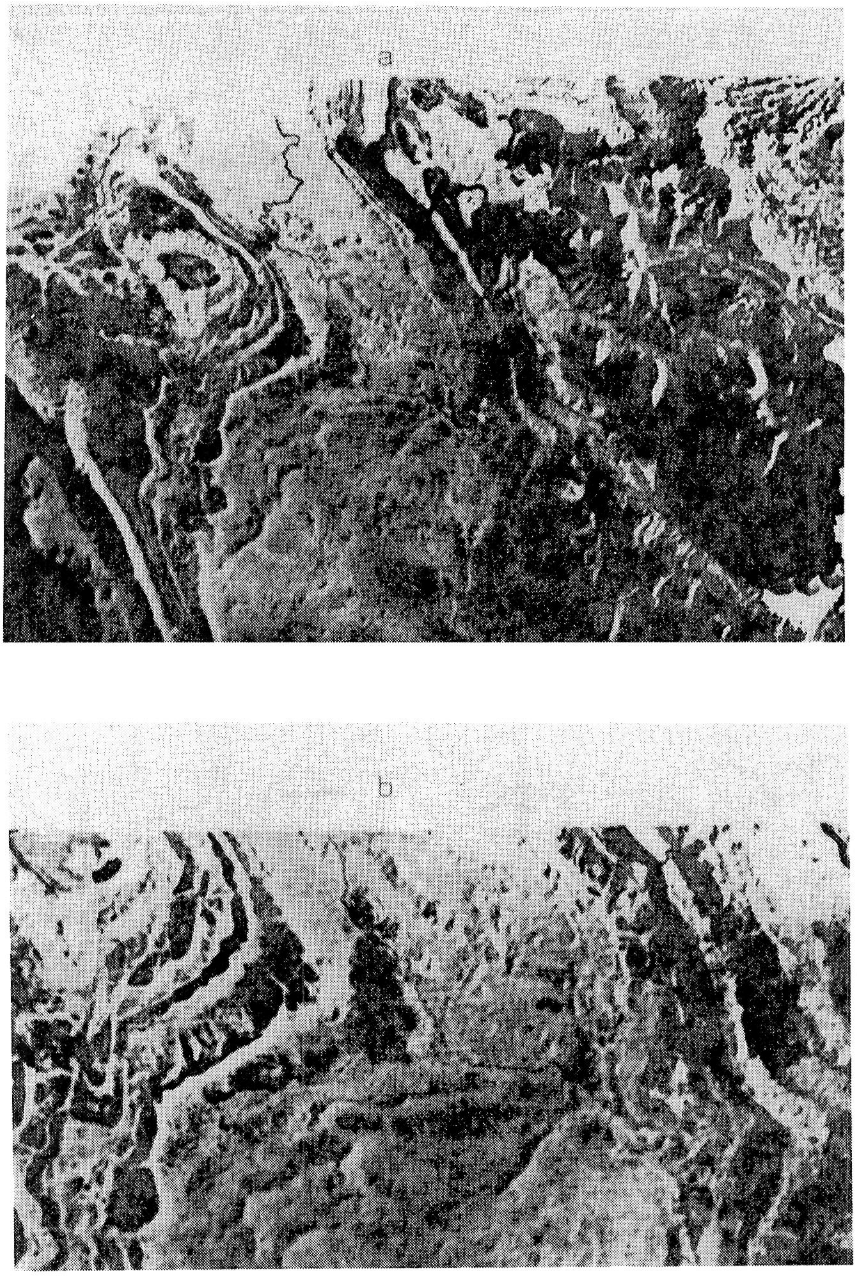

Fig. 1 - Examples of Landsat images. a) Chiguao River headwaters. Auyantepuí to the right. b) Detail of same area, showing sandstone "bridge" between Guiquinima and Auyantepuí.

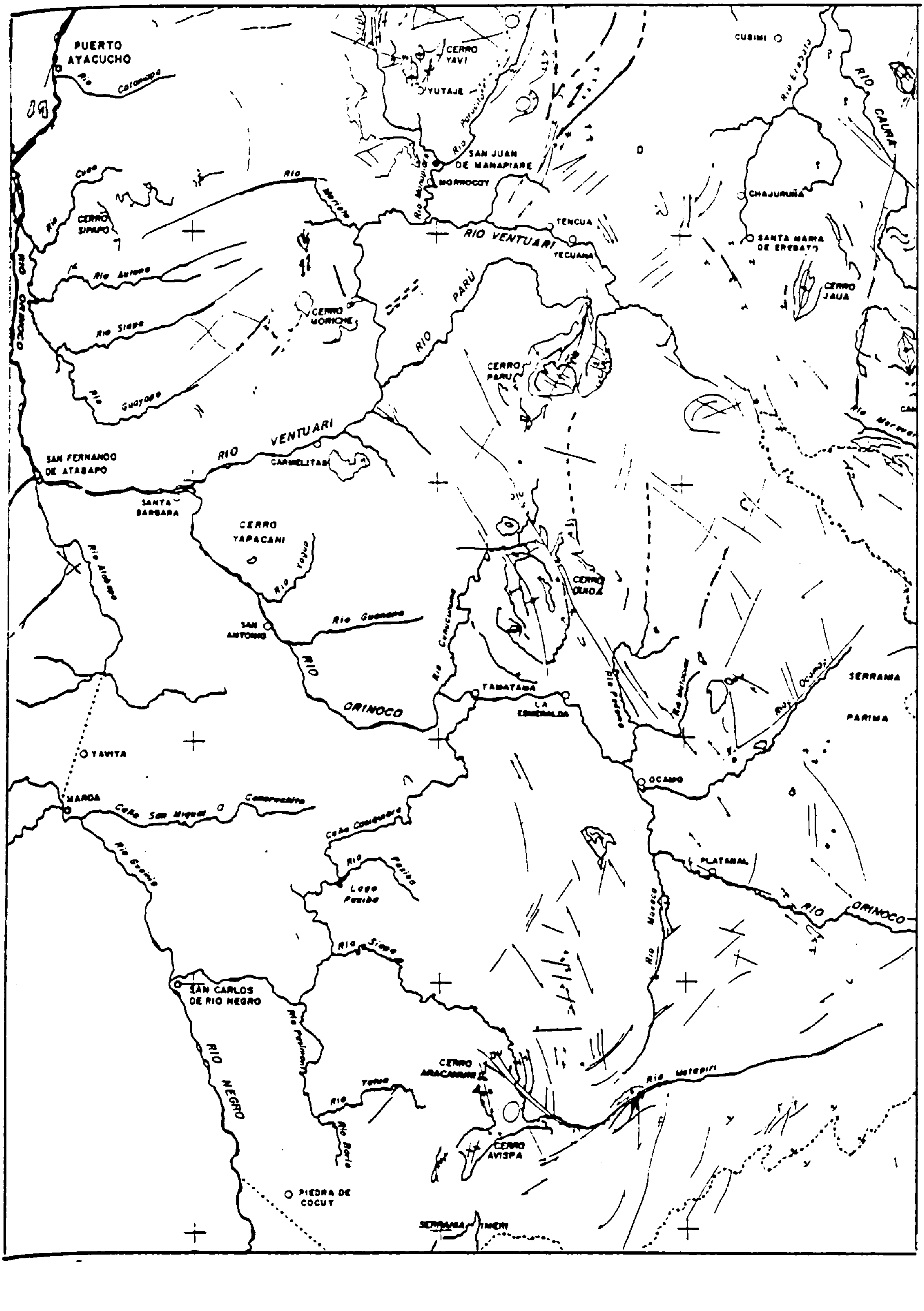

Fig. 2 - An interpretation of radar images of Amazonas Territory (from Yanez, 1973). Approx. area: 100,000 km^2.

exposure is limited to about 75,000 km^2, mostly in southeastern Venezuela, and this is the area on which discussion focuses.

The Roraima Group divides upward into three formations -- Canaima, Guaiquinima, and Auyantepui -- each with a rather distinctive geomorphological signature or surface expression. The lower and upper formations are poorly cemented quartzose or feldspathic sandstones, arkoses, conglomeratic sandstones, and conglomerate lenses, all apparently deposited in a fluvio-deltaic environment. The Canaima is poorly exposed under dense rain forest and complete stratigraphic sections are few. The Auyantepui is a massive cliff-former, with nearly vertical 500 m high scarps that culminate in flat-topped or bowl-shaped, broad synclinal folds of the table mountains (tepuís) that rise precipitously above the Orinoco-Caroní lowlands (Fig. 3). Carbonate content of the rocks based on soil analysis is less than 4%, yet summits of some tepuis (Duida, Guaiquinima) are marked by 300 m deep, 2 km long, fluted karren "pseudokarst" shafts (cimas) developed in massive but poorly indurated quartzitic rocks. Local shale members apparently weather to hydromorphic clays and silts, which in the past were redeposited in alluvial flood plains, but do not constitute much of the sediment transported today.

The Guaiquinima is stratigraphically distinct because of the presence of volcanic tuffs, intercalated with hard beds of red or green jasper, and associated with intrusive dolerite or hornfel dikes or sills. Rb/Sr dating has yielded dates that range from 2100 m.y. to 1500 m.y., and are the only clue to relative age. Dikes where exposed surficially weather to positive relief elements of the landscape.

Geomorphology

The geomorphology of Venezuelan Guiana is an almost classic case of landform evolution controlled by lithology and structure. Although there is some evidence of post-Roraima deformation into gentle, regional-scale anteclise-syneclise folds, and minor reactivation of basement block-faulting, nothing indicates that the region has been other than a stable craton of non-deposition for the last 1500 m.y. This requires speculation about the rate and magnitude of the long-term geomorphic evolution of the region. In the present climate, scarp retreat in tepuís clearly progresses rapidly. Surfaces are fresh and lack case-hardening, and large blocks weighing hundreds of tons are known to "peel" from tepuí-scarps with great regularity. Furthermore, radiocarbon dates from organics beneath a 15 m thick sand-gravel overburden in alluvial placer workings yield ages of only 3,000-10,000 yrs., indicating an enormous rate of denudation and flux during the Holocene, yet streams today are clear-flowing and sediment transport is minimal even during peak discharge. Furthermore, if stripping of the shield had occurred at the same magnitude and rate for 1500 m.y., clearly no Roraima rocks should remain! Unfortunately, we also have no hard evidence or even a "feel" about climates, landforms, and erosion rates for the greater span of Phanerozoic time.

Other evidence of changing climate comes from extensive alluvial fans, such as those near the Indian mission at Kamarata in the Chiguao River valley southeast of Auyantepui (Fig. 4). These densely jungle-covered surfaces, as much as 6 km broad, clearly did not form under the present climate or cover. Elsewhere, as near Kavanayen Mission, are flat-topped sloping surfaces which may be true pediments rather than the ubiquitous, stripped surfaces characteristic elsewhere. Are all these, along with broad alluvial floodplains such as mark the Kukenan River valley farther east, relicts of a Pleistocene, or earlier, semiarid to arid climatic regime? The concept of global climatic

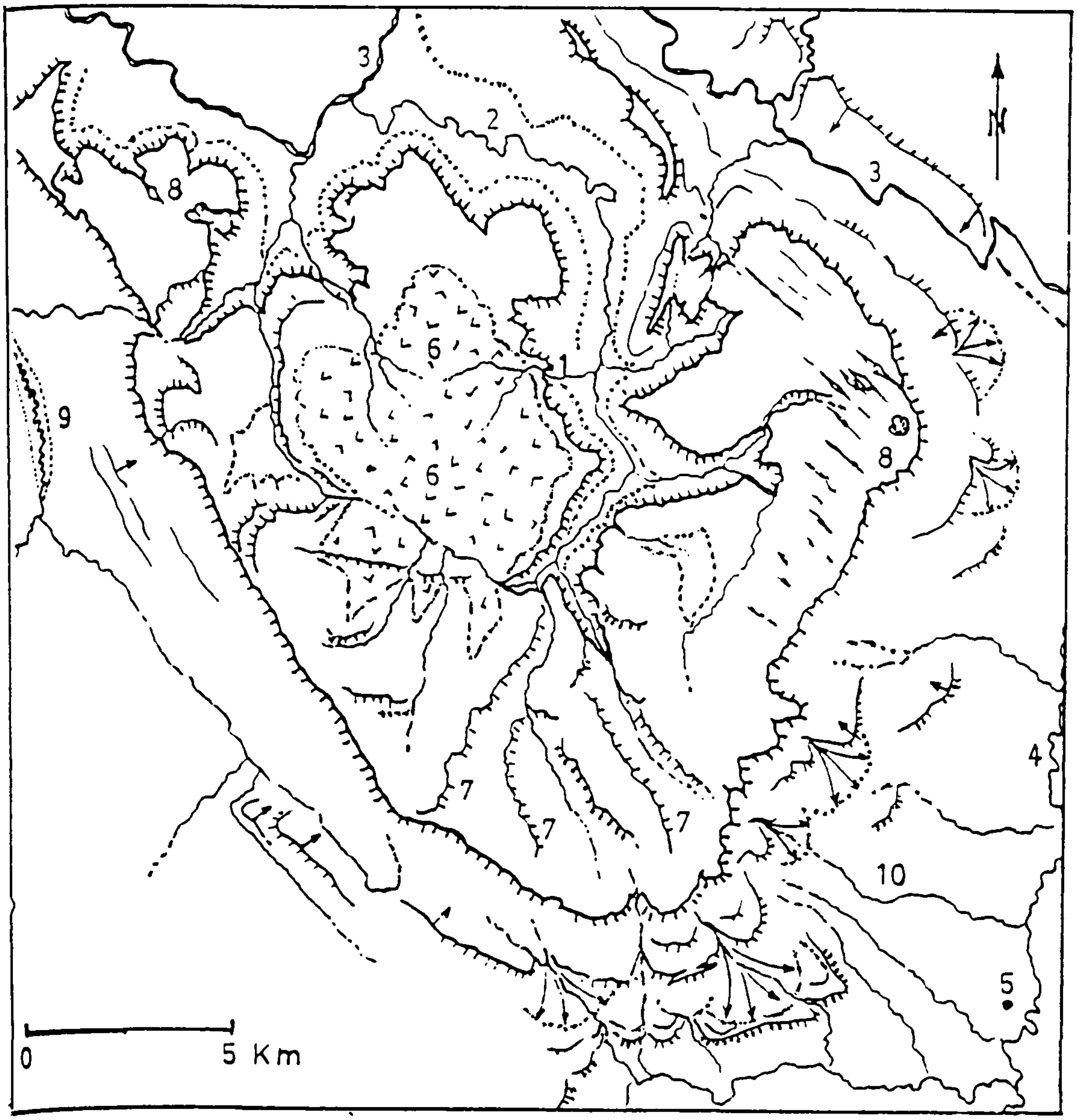

Fig. 3 - Geomorphological map of Auyantepuí, 1 - Angel waterfall. 2 - Churun River. 3 - Carrao River. 4 - Akanan River. 5 - Kamarata. 6 - Probable sill of basic rocks. 7 - Scarps, 100-150 m high, on Auyantepuí. 8 - Pseudokarst landforms. 9 - Kukurital River flood-plain. 10 - Alluvial fans and apron near Kamarata. Hachured borders are major scarps around Auyantepuí.

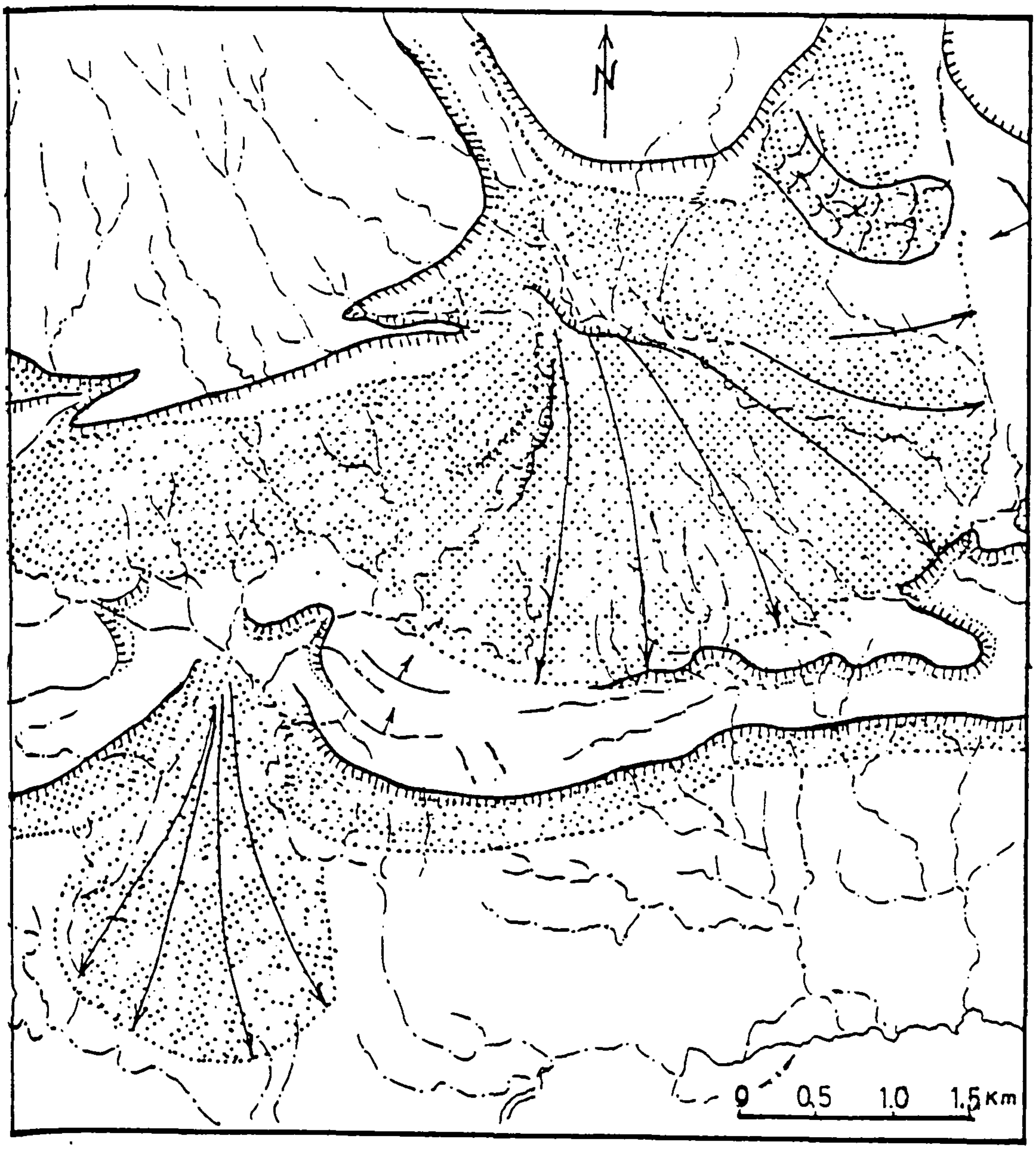

Fig. 4 - Alluvial fans west of Kamarata. Hachured borders show scarps; stipples are alluvial fans.

change and an arid episode at low latitudes has been proposed, on equally tenuous evidence, by Damuth and Fairbridge (1970), Tricart (1974), and Wallace et al (1960).

The region is located about 4° to 6° North, 59° to 64° West in the moisture-laden subtropics. There is no pronounced dry season, and annual rainfall on higher tepuis may exceed 5000 mm. More than three-quarters of the region is tropical rain forest (bosque), the remainder tropical grassland and brush savanna (selva). The latter apparently is natural in part (as on some positive-relief dikes), but much is clearly anthropic, owing to clearing and burning. Once vegetation is removed and a thin surface ferricrete-silcrete layer breached, "instant badlands" form, carving canyons 30 m deep in a few years. These rapid changes in landscape need repititive monitoring regionally to determine the variations in hydrology, erosion, and sediment flux that result from changing landuse in a region which has considerable mineral, soil, and water resources but is very fragile under human impacts. For example, under enhanced development sediment flux to streams may rapidly increase and substantially impair the hydrologic regime. The world's highest waterfall (Salto Angel) with direct free-fall in excess of 1000 m is fed by a stream only 4 km long that originates in rain forest atop Auyantepuí. Removal of this forest assuredly would decrease or greatly vary flow, and inasmuch as the region has important hydroelectric potential, any cumulation of flow changes is an important economic consideration. Likewise, what would happen to agriculturally attractive floodplains, such as along Kukenan and Kukurital rivers, under strong flooding and regular overbank discharge and renewed deposition of coarse-grained clastic debris, an event that does not now occur?

Role of Space Imagery

The foregoing recital lists only a few examples of how geomorphic change has and continues to modify a major region of South America. But how does all this relate to the value of sequential acquisition and analysis of high-altitude and space imagery? Population explosion in South America inevitably is leading to the opening of virgin interior lands; thus continuous monitoring of landscape change clearly is of great interest. Space imagery, perhaps even for several decades, accompanied by repetitive radar imaging and high-altitude color-IR photography will tell much about such important matters as the gross magnitude of denudation and erosion, actual rates and mode of scarp retreat, the role of sediment flux and flooding, and continuing vegetative change under the present climatic regime. The resolutional capability of the new Large Format Camera System seems to offer much potential for monitoring important site-specific changes and problems.

In a purely scientific sense, sensor products may help identify sites of reasonable access that can be studied to provide better documentary evidence of an earlier arid climate regional pedimentation episode or cycle and long-term changes in landscape evolution.

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