

GOMORPHIC ANALYSES FROM SPACE IMAGERY

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One of the most obvious applications of space imagery to geomorphological analyses is in the study of drainage patterns and channel networks. Landsat, high altitude photography and other types of remote sensing imagery are excellent for depicting stream networks on a regional scale because of their broad coverage in a single image. They give us a valuable tool for comparing and analysing drainage patterns and channel networks all over the world.

There are three aspects to be considered in such a geomorphological study: (1) Origin, evolution and rates of development of drainage systems, (2) Topological studies of network and channel arrangements, and (3) the adjustment of streams to tectonic events and geologic structure (i.e., the mode and rate of adjustment).

(1) Origin and rates of evolution of a drainage system.

The origin and early development of stream channels has not often been documented. Glock (1931) outlined a theory on the stages of drainage evolution as a network is established, elaborated and integrated. Research by Schumm (1956) and Hack (1965) have given some insight into the changes made in a network as drainage patterns grow. A study by Ruhe (1952) gave a handle on the time scale involved in stream development on tills of different ages in Iowa. Numerous papers by Abrahams (e.g., 1975, 1977) have tried to ascribe changes in drainage networks to factors such as relief and available space. It should be pointed out that, with the exception of Glock's theoretical paper, all these (and other) studies have been done on the basis of detailed, "on the ground" or topographic map analyses.

With space imagery covering the world, we can find drainage nets in all stages of development. Using space as a substitute for time, we can work out the evolution of a typical network. In addition, the patterns can be related on a regional scale to physical and geologic characteristics. Moreover, with continuous coverage, changes over time can be documented to produce rates and actual manner of evolution.

(2) Topological studies of network and channel arrangements.

Smart and Moruzzi (1972) gave geomorphologists a basis for the analysis of drainage network topology. Fig. 1. Their study and that of Morisawa (in press) dealt with distributary drainage patterns on deltas, Fig. 2. The Smart and Moruzzi system of topologic analysis has more recently been applied to braided stream channel configurations (Morisawa and Ginzler, in preparation), Fig. 3. Krumbein and Orme (1972) applied the Smart and Moruzzi technique of analysis to a braided channel net that they

had mapped in the field. All of these studies have been done from networks derived from topographic maps or in the field where the patterns were "frozen" in time. However, each of these types of distributary nets are known to be ephemeral, i.e., in a state of constant flux. Space imagery and high altitude photography will allow such patterns to be followed as they change over time. Research of this type may provide valuable information of stable (and unstable) components of the channel systems and insight into long term characteristics of the patterns.

(3) The adjustment of streams to tectonic events and geologic structure.

It is a well-known axiom in geomorphology that structure has a great influence on drainage patterns (Zernitz, 1932). Many detailed studies have related drainage networks to the underlying geologic structures. Morisawa (1963) indicated the expected frequencies of flow directions in dendritic drainage patterns and showed the influence of foliation on skewing the observed frequencies. Judson and Andrews (1955) and Cox and Harrison (1979) gave evidence that joints can influence direction of stream flow. Orientation of streams in the Piedmont of Georgia was ascribed to various structural controls by Woodruff and Parizek (1956). Hack (1966) described circular stream patterns guided by exfoliation in the underlying rocks in an area of North Carolina. Many other papers in addition to those cited have shown how rivers are influenced in their flows by geologic structure.

The use of such knowledge can be instructive when viewing remote imagery on a global scale. Analysis of drainage networks can allow determination of many structural elements in regions we are unable to visit. Such imagery can enable us to examine large regions to determine geomorphic similarities and differences on a global scale. the availability of world-wide coverage of space imagery may allow us to trace the rate and manner of stream adjustment to the underlying structure and thus solve many longstanding problems of drainage evolution. And with successive imagery over time, we may be able to see the actual adjustments as they take place. In this way we may be able to peer back into the geomorphic past.

Moreover, studies have shown that fossil drainage systems, now buried beneath the surface are revealed by shuttle radar imagery. McCauley and others (1982) thus discovered ancient buried channels under the Sahara sands. Various kinds of space imagery may, hence, enable us to unravel not only the evolution of drainage and paleolandscapes but also to determine former climatic regimes.

Associated with this aspect of applications of space imagery, but with a broader implication, is its use in the study of tectonic geomorphology. Although plate tectonics has dominated geologic thought and research for many years now, it is only recently that this idea has purposefully been related to the concomitant landforms and processes well-known in geomorphology

(Ota, 1980). Thus a new setting has appeared for geomorphological analyses where continental surfaces are studied to provide evidence in their landforms of the nature of their tectonic history (Ollier, 1981).

Geomorphology cannot be isolated from other geologic phenomena and it must be integrated with our modern knowledge of tectonics. Subduction, uplift and plate movements have an effect on landforms and geomorphic processes, hence configuration of landforms can be used to interpret tectonic history (Kennedy, 1962 and Morisawa, 1975). The interplay of tectonic forces and geomorphic processes of denudation on the rocks of the earth results in characteristic landforms depending on the dominance of any of the involved factors of tectonism, denudation and earth materials.

At the 1984 Binghamton Geomorphology Symposium on Tectonic Geomorphology ample evidence was given that tectonic history can be read from geomorphology of the surface (Morisawa and Hack, in press). Landsat, Seasat and other types of space imagery will be most helpful in studies which seek to interpret tectonic events from drainage nets and other surface features. For example, Lowman (1976) used lineaments and drainage anomalies shown on Seasat imagery to delineate faults in California. Morisawa (1975) used ERTS imagery to trace lineaments and drainage patterns in the Adirondacks in an effort to document faulting and neotectonic movements in relation to soft sediment deformation.

The large size of some structures can be more easily recognized from space imagery which gives broad areal coverage, yet even minor details can be seen. Both aspects provide information for interpreting and integrating regional geology and tectonic events from landforms. A whole new world has opened up before the geomorphologists of the future.

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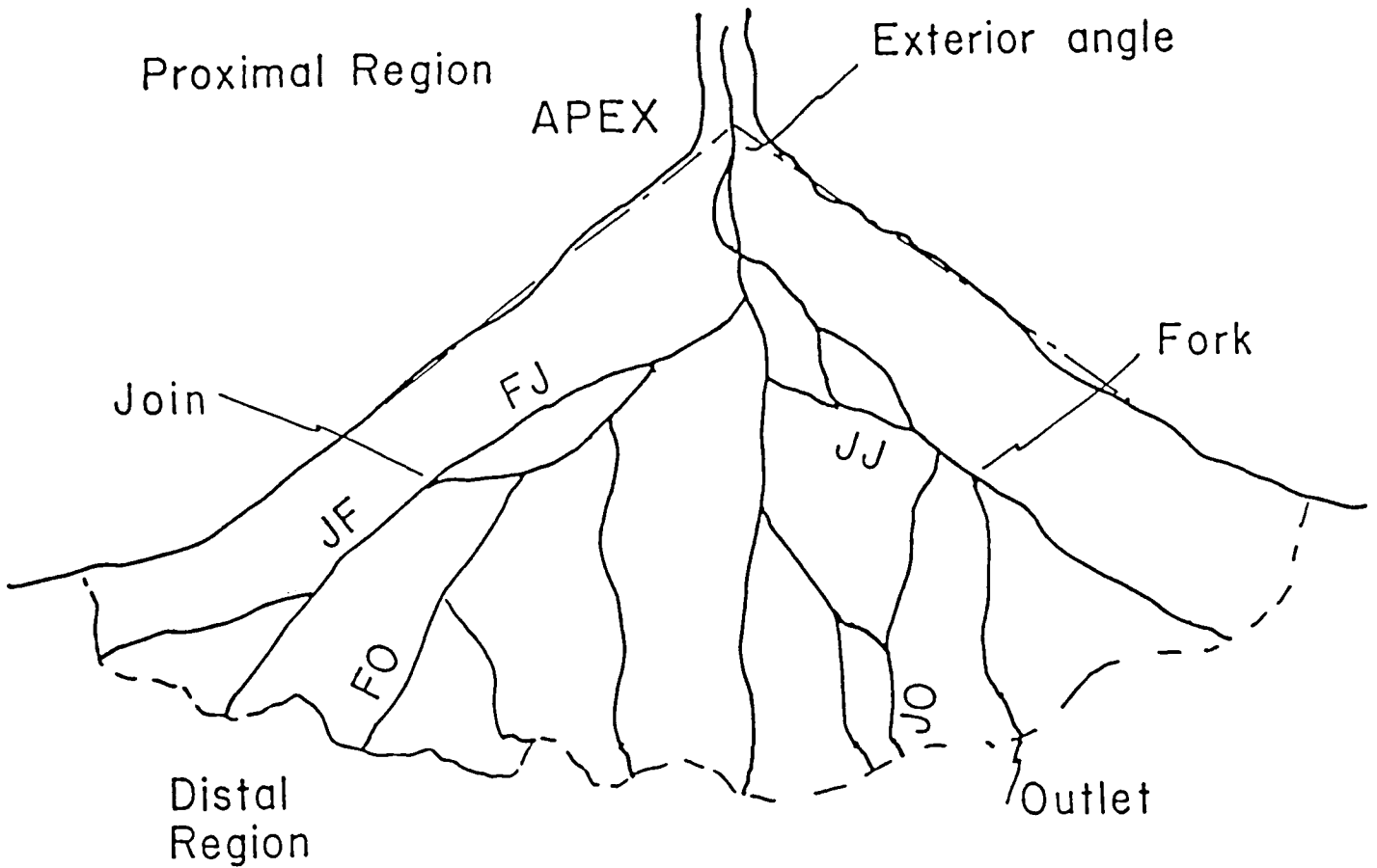


Figure 1. Nomenclature for topologic analysis of distributary networks. FF = link between two forks, FJ = link between fork and join, FO = link between fork and outlet, JF = link between a join and fork, JJ = links between two joins, JO = link between a join and outlet. After Smart and Moruzzi, 1972.

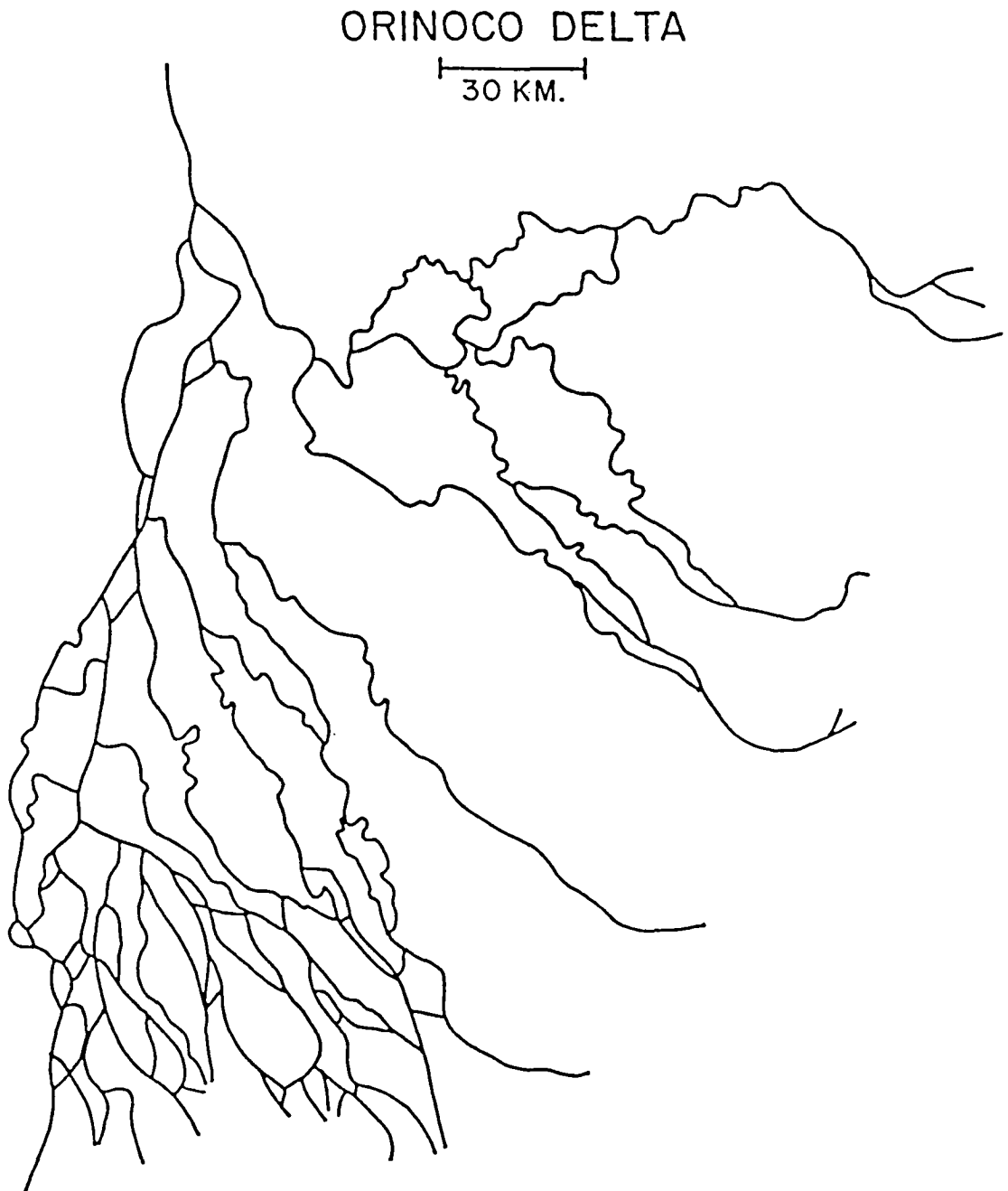


Figure 2. Distributary network of the Orinoco delta.

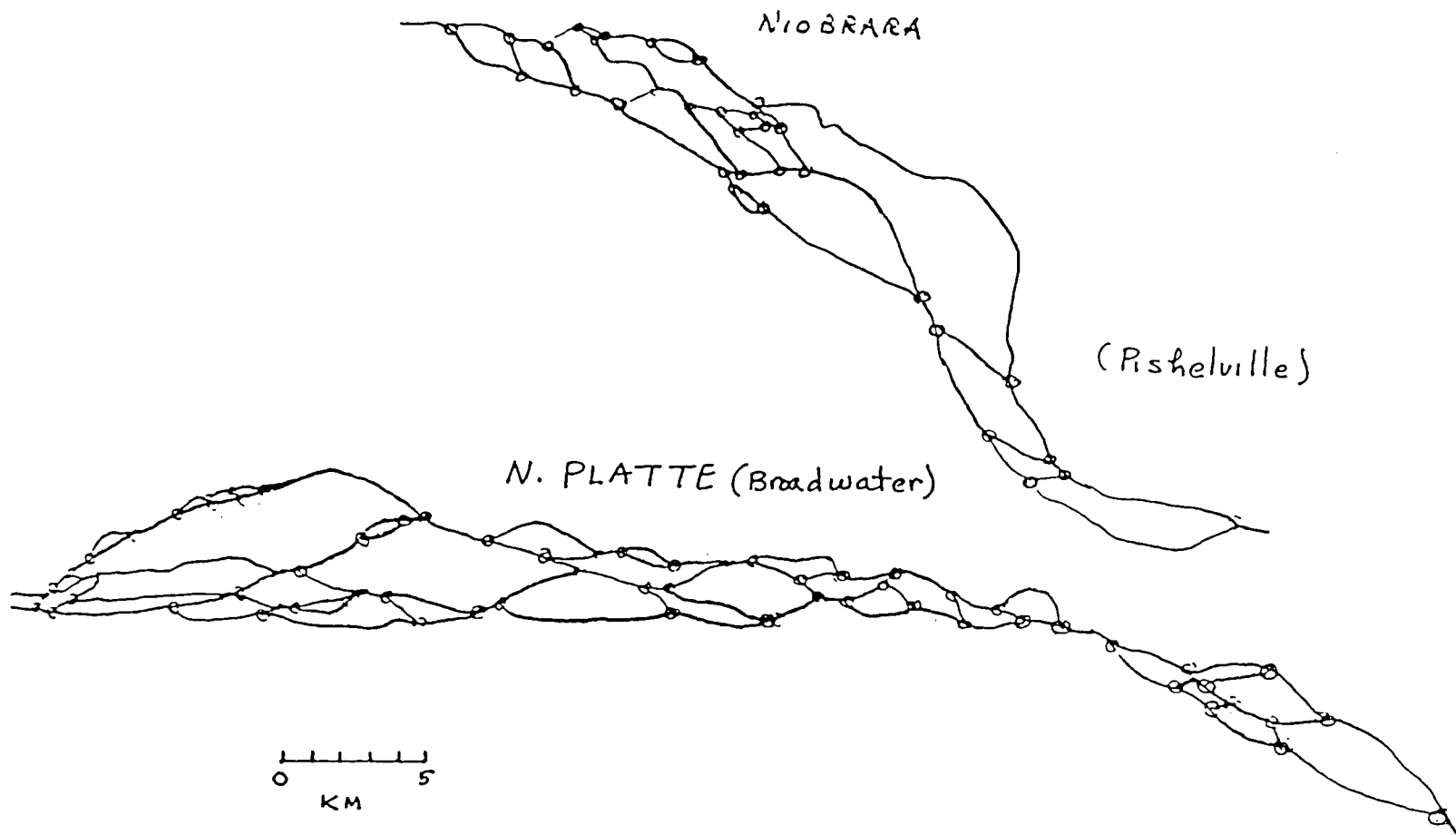


Figure 3. Braided channel networks.