Use of the Synoptic View: Examples from Earth and Other Planets

B. K. Lucchitta
U.S. Geological Survey, 2255 North Gemini Dr., Flagstaff, AZ 86001

Introduction

Space technology has added the synoptic view to other techniques used in geomorphology. Synoptic views are provided by spacecraft images or by application of space technology to time-honored information systems. Examples of spacecraft images of Earth are Landsat, Seasat, and the SIR (Shuttle Imaging Radar) series. Examples of applied space technologies include the digital conversion of topographic maps to shaded relief maps and digital correlation methods. From the study of other planets we have learned that synoptic views enable the deciphering of a planet's history: large features are identified and mapped before small ones; studies proceed from the general to the specific. On Earth, we generally recognize smaller features and study specific processes first, then extrapolate toward larger features and a general synthesis. With the advent of space images of Earth, perhaps the time is ripe to employ the methods used for other planets to the study of terrestrial geology and geomorphology. The following examples illustrate the use of regional-scale studies on Earth: the application of synoptic-view images in Antarctica, the use of digital methods and correlations of multiple data sets in regional studies, and some benefits to our understanding of terrestrial geology that have been obtained from analyses of other planets.

Antarctica

Because of the remoteness of its vast regions, Antarctica has more to gain from exploration by space-age methods than do the other continents. The synoptic view of images from space is helpful in preparing planimetric maps, in monitoring coastlines and ice streams, and in identifying blue-ice areas. Maps are essential base materials for the interpretation of geologic, geomorphic, and geophysical features. In Antarctica, where little ground control is available, the Landsat digital satellite images of the multispectral scanner (pixel size about 80 m) and of the Thematic Mapper (pixel size about 30 m), and the photographs of the large-format camera carried by the shuttle (resolution about 20 m) can increase the accuracy of maps at medium scales. NOAA-AVHRR (advanced very high resolution radiometer) images obtained by weather satellites (resolution about 1 km) can facilitate the preparation of maps at small scales.

Images from space obtained at different times also help in the monitoring of changes in coastlines and ice sheets. Repeated coverage by aerial photographs is much more costly. Advances and retreats of glaciers, ice streams, and ice shelves may reflect changes in climate. Monitoring of the west antarctic ice sheet is particularly important, as it rests on bedrock that is largely below sea level (Drewry and Jordan, 1983); invasion of sub-ice sea water could cause rapid disintegration of the ice sheet and a world-wide rise in sea level.

Flow-lines in ice streams are exceptionally clear on Landsat images, especially on those taken at low sun angles. The location of ice-intake areas can thus be determined; this information, when combined with depths to bedrock from radio-echo sounding, may lead to an understanding of the mass balance of the ice sheets. Radar images of the ice sheets from anticipated missions in polar orbit would have the advantage of cloud penetration and would further elucidate the detailed surface structure of the ice sheets; acquisition of such radar images is highly recommended.

Synoptic views over Antarctica also aid in the rapid recognition and location of blue-ice areas, which have recently acquired importance because they contain lag deposits of meteorites (Williams et al., 1983). Digital methods applied to Landsat multispectral images can highlight blue-ice areas, and thus locate them with a minimum of effort.

Digital Methods and Correlations

Digital methods that were first developed for space images can be applied to terrestrial topographic, geologic, or geophysical data. If of regional scale, these data can produce synoptic images and permit computer correlation of superposed data sets. Computer transformation of topographic maps into shaded relief maps yields images that are not marred by varied albedoes of the scene or cultural overprints; therefore, these images are ideal for regional analysis of structure and geomorphology. Megalineations that bound major physiographic provinces are easily recognized, and variations in regional drainage patterns permit delineation of distinctive rock types, structure, and geomorphology. Careful mapping of geomorphic provinces and structural lineations on these images, combined with studies of the geologic literature, may contribute significantly to an understanding of landform development.

Small-scale digital shaded relief maps or other synoptic-view images are ideal for superposition of other data sets to provide visual displays or to furnish computer correlations. Computers can produce two-dimensional histograms that correlate color, albedo, numerical identifiers of drainage patterns, elevations, gradients, digitized geologic units, and geophysical data such as gravity, aeromagnetics, and heatflow. These correlation techniques have been successfully applied to data from other planets, but their use on Earth has only begun. Worldwide digital maps of topographic and geologic data and their correlations may point toward relations on a large scale that are as yet unknown.

The Planetary Experience

The synoptic view has helped us to understand the history of other planets. Some of these insights may contribute to a better knowledge of the history of Earth:

> Geologic mapping of the Moon taught us that early accretion leaves planetary surfaces scarred by craters. Intense meteorite bombardment and its consequences probably also profoundly influenced the development of the early Earth.
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> The cratering record on the Moon and other bodies shows that some impact bombardment extends into recent times and that impacts on Earth may have occurred periodically. From this and other observations stems the hypothesis that links the extinction of some terrestrial species to impacts. Also, we are beginning to acknowledge the importance of other

catastrophic events, and we are realizing that perhaps the principle of uniformitarism as commonly interpreted has restricted our thinking: geologic processes operating on Earth may indeed have changed with time.

One-plate planets with thin atmospheres lack pronounced endogenic or exogenic destructive forces; landforms consequently develop fully. On Earth, landforms are obliterated nearly as fast as they form, and features tend to remain small. On Mars we see huge volcanoes, landslides, debris flows, possible rock glaciers, and landforms carved by floods or ice. We see tectonic features such as grabens, rifts, and folds (wrinkle ridges) in their original constructive forms. Studies of these features are elucidating or refining our appreciation of processes on Earth.

Wind features on Earth are rarely preserved because they are quickly destroyed, mostly by fluvial activity. Mars, however, is a natural laboratory where wind features, especially those carved by erosion, are observed in pristine form. We have come to interpret some desert landforms on Earth in the light of what we have learned from Mars (Breed et al., 1982). Antarctica is a cold dry desert region; its ice sheets locally display sweeping sinuous scarps and ridges that are similar to wind-formed features on Mars; perhaps the Martian analogs will aid in the interpretation of these Antarctic features.

Conclusions

The synoptic views afforded by spacecraft images, the application of digital methods to terrestrial data, the approach to problem-solving used on other planets, and the relevancy of extraterrestrial experiences to terrestrial geomorphology all contribute to a new awareness in the study of terrestrial landforms and processes. Many uses can easily be added to the brief list given above, as the potential of geomorphologic studies on a global scale is only beginning to be realized.

References

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