morphic, not bedrock mapping, applications of airborne imagery. Two factors control the value of a particular image in a particular study—scale and type of imagery.

Small scale imagery, less than 1:40,000, is particularly useful in broad, regional studies of structural trends, regional drainage pattern analysis, and lineament mapping. The larger scale imagery is more useful in fracture trace studies, local drainage pattern and single channel feature studies, and local tonal anomaly studies. Large-scale imagery may, of course, be compiled into a mosaic.

A wide variety of image types are available today. The most commonly available are black and white photography with many possible filter combinations, black and white infrared photography, color and color infrared (false color) photography, and thermal infrared and radar imagery. These images have a large range in cost and applicability. As a tool of the photogeomorphologist, color aerial photography appears to be the most generally useful for a basic study. Black and white, and black and white infrared, photography are the least expensive and quite useful. The other types of imagery have special, and sometimes very useful, applications.

Of value in some cases is sequential imagery showing, for example, variations of vegetation throughout the year. Such time-dependent changes in terrestrial features may have significance in photogeomorphic exploration.

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RESPONSE OF STREAMS TO STRUCTURAL UPLIFT

Drainage anomalies over structural uplifts in regions of low relief (less than about 150 ft local relief) and unconsolidated rocks are of 2 types—drainage pattern anomalies and single-channel anomalies. Field studies and model investigations have revealed certain basic stream responses to local uplift. In areas of generally uniform regional slope, local reversals or marked divergences of drainage pattern from the regional slope are structurally significant. Radial drainage patterns (full 360° radial patterns) are always anomalous. Concentric drainage is due to the exposure of beds of different resistance and may, or may not, be present. If the unconsolidated material is uniform or very poorly bedded, the local shifting or deflection of drainage is significant, but in well-bedded rocks it may be merely homoclinal shifting downdip. Marked local, opposed drainage deflections are apparently due to almost continuous uplift favoring continuous lateral shifting rather than accelerated incision.

In unconsolidated rocks, the most important single-channel response to slight structural uplift is the local channel width-depth ratio. Changes in this ratio may be seen on aerial photographs. Such changes, however, may also be due to changes in lithology or in tributary streams. Decreases in gradient (such as upstream from a structure) result in increased channel width-depth ratio and increases in gradient decrease width-depth ratio. Meander compression or local changes in sinuosity may be due to structure or lithologic difference. Color aerial photography may aid in distinguishing structural and lithologic causes of single-channel features.

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SOUTHERN LABRADOR SEA—KEY TO MESOZOIC AND EARLY TERTIARY EVOLUTION OF NORTH ATLANTIC

Geophysical studies made in the southern Labrador Sea and related to the drilling of deep holes there, have given evidence of the change from a two-plate to a three-plate spreading geometry in the evolution of the North Atlantic and Labrador Sea. The change is dated at about 60–65 m.y. ago and can be recognized by the magnetic anomaly pattern and the basement topography.

By use of magnetic anomalies and fracture zones, the stages in the evolution of the North Atlantic can be described as follows.

1. 180 m.y. African plate started to separate from North American plate accompanied by shearing between Africa and Europe.

2. Between 180 m.y. and 80 m.y. Separation of European and North American plates along Greenland-Spain fracture zone gave rise to primitive Iceland basin and Rockall trough and separated Spain from the Grand Banks. Orphan Knoll, Porcupine Bank, Flemish Cap, and Galicia Bank were detached and displaced.

3. 150 m.y. to 80 m.y. Spain rotated counterclockwise about rotation pole in Paris to open Bay of Biscay.

4. 80 m.y. to 60 m.y. Spreading occurred between North American plate and plate comprising Greenland, Rockall plateau, and northwest Europe, to create Labrador Sea and North Atlantic.

5. 60 m.y. Rockall plateau separated from Greenland along new spreading axis on east side of primitive Iceland basin. Triple junction developed, and spreading axes and fracture zones shifted to accommodate new geometry.

6. 60 m.y. to 47 m.y. Simultaneous opening of Labrador Sea, Reykjanes Ridge, and North Atlantic.

7. 47 m.y. Greenland virtually stopped moving relative to North America, and Labrador Sea growth finished.

8. 47 m.y. to present. Reykjanes Ridge and North Atlantic grew as European plate separated from North America–Greenland plate.

Paleogeographic reconstructions have been made and their validity tested against the data obtained from drill sites on Leg 12 of the Deep Sea Drilling Project.

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TERTIARY LIMESTONE DIKES, OAMARU, NEW ZEALAND

Indurated calcarenite and calcilutite dikes cut vertically through lower Oligocene volcanic sediments in the Oamaru region, east coast, North Otago, South Island, New Zealand. Individual dikes extend more than 10 m vertically and can be followed for much greater distances along regular or irregular strike. Field relations and paleontologic data suggest the limestone dikes were filled from above; at least 2 younger Oligocene formations contributed debris. Most dikes comprise several sharply defined layers of differing texture, composition, or structure parallel with dike walls. Subhorizontal layering, with either grading or cross-stratification, is also present but less common. Most composite dikes are less than 10 cm thick, but they range up to 30 cm; many of the dikes pinch and swell along both strike and dip. Flow structures are well developed between 2 vertical layers exposed in strike section along one dike. Limestone filling the interstices of a pillow lava was apparently supplied through channels now preserved as dikes.

Some dike layers are well-sorted bioclastic sand, but most layers consist of calcareous mud, with varying

proportions of fossils (planktonic and benthonic forams, bryozoans, echinoderm debris, mollusk debris, brachiopod fragments, calcareous algae, sponge spicules), glauconite, tuff fragments, quartz, feldspar, rare pyroboles, clay minerals, intraclasts (probably mostly from older dike layers), and rare pellets.

The polyphase dikes are interpreted as infillings of fissures that repeatedly opened on the flanks of volcanic mounds. Infillings appear to be more varied than the possible source rocks and probably record transient sedimentation.

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PETROLEUM EXPLORATION WITH RADAR—EASTERN PANAMA AND NORTHWESTERN COLOMBIA

Petroleum exploration in eastern Panama and northwestern Colombia has gained impetus from recent side-looking radar mapping. Radar-derived geologic information is now available for approximately 40,000 sq km where previous reconnaissance investigations have been extremely limited because of inaccessibility and perpetual cloud cover.

With radar imagery as the sole source of remote sensing data, the distribution, continuity, and structural grain of key strata provide evidence that the eastern Panamanian Isthmus can be divided into 3 main physiographic-structural parts. Two composite coastal mountain ranges are separated by the Medial Basin which trends southeastward from the mouth of the Bayano River to the Atrato River valley of northwestern Colombia. Within the Medial Basin, the most obvious site for petroleum exploration, the majority of clearly exposed surface structures are not particularly attractive prospects because prime reservoir strata have been stripped from their crests. However, several large geomorphic anomalies which have been mapped in the Medial Basin may be reflections of subsurface structures having a complete stratigraphic section. The possibilities of gravity-type entrapment in fractured organic shales, siltstones, and carbonates have been suggested along the southern synclinal trends of the Medial Basin. The southwestward extension of the Medial Basin trend, coincident with unique beach ridges from a possible granitic source, provides an attractive petroleum prospect in the western part of the Gulf of Panama. The occurrence of active shell bars in the Bay of San Miguel and present reef trends on the northern Caribbean coast suggest possible offshore sites for geophysical surveying.

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GYPIDULID BRACHIOPODS: THEIR LIFE POSITION AND PALEOENVIRONMENT

Life assemblages of 2 species of gypidulid brachiopods, preserved in their original positions of growth, have been collected from Upper Silurian and Lower Devonian limestones of the Appalachian basin. The 2 assemblages inhabited the same environmental locus at different times in a transgressing carbonate sea. The earlier *G. prognostica* is in the Keyser Formation in Pennsylvania, Maryland, Virginia, and West Virginia, and the later *G. coeymanensis* is found in the Coeymans Formation of New York state.

The gypidulids, in both cases, lived clustered in a beak-down position on poorly sorted skeletal sand substrates in association with a diverse faunal assemblage of brachiopods, bryozoans, crinoids, and trilobites. The specimens appear to have no pedical openings, indicating lack of pedical development in mature forms. The inner prismatic shell layer in the pedical umbo is many times thicker than the total shell elsewhere on the organism. The resulting weighting of the pedical umbo and lateral contact with other individuals in the cluster promoted an upright, posterior down orientation.

Gypidulids are restricted to shallow (near, but above wave base) shelf environments. Onshore skeletal barrier sands and skeletal lagoonal muds, as well as offshore fossiliferous muds, are barren of gypidulids. The gypidulid environmental position occurs only in transgressive stratigraphic sequences.

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TOWARD A MORPHOLOGICAL CLASSIFICATION OF ORGANIC REEFS AND REEF COMPLEXES

Most of the literature concerning the definition of organic reefs (bioherms and biostromes) and of similar carbonate accumulations emphasizes the genetic and biostratigraphic classification of these features. To the writer's knowledge, no previous attempt has been made at a purely morphological classification. "Reef complexes" have in recent years been called "bank atolls," "reef-fringed carbonate banks," and "biohermal flanked biostromes." Such hybrid names appear to impose a dualistic origin on a reef complex, although it is obviously a genetic unit, and they should therefore be avoided. Henson's "reef complex" included the sediments genetically associated with the reef *sensu stricto;* these are not "banks" or "biostromes" within the generally accepted meaning of these terms. The writer therefore has introduced the term "cycloherms" (circular reefs) for the gigantic shelf atolls such as those in the Devonian of western Canada, in the Permo-Pennsylvanian of West Texas, and in the Cretaceous of Mexico. In addition, the term "phragmoherms" (wall reefs) was introduced for fringing reefs and barrier reefs such as those in the Triassic of the Alps.

In recent years bioherms proper have been called "pinnacle reefs," "haystack reefs," and other such terms which bear little relation to their actual morphologic proportions. Such names are based on the reef shapes commonly seen in cross sections of exaggerated vertical scale, and create erroneous impressions of their true relative dimensions. The new, unequivocal names proposed for these bioherms are "aspiherms" (shield reefs) for the pinnacle type and "trapeziherms" (table reefs) for the flat-topped haystack type.

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EXPLORATION ON CONTINENTAL SHELF OFF NORTHWEST AUSTRALIA

Exploration of a 144,000-sq mi rank wildcat area in offshore northwestern Australia began in 1964 with analog seismic surveys. Each year additional surveys have been carried out with a steady improvement in data quality due to advantage being taken of technological advances of the industry.

Interpretation of these data and incorporation of available drilling results have permitted structural and depositional models to be rationalized for post-Paleozoic time-rock sequences. Improvements in drilling technology have allowed locations to be sited in greater water depths confirming depositional and structural models.