buried relief features, whether formed on land or under water. Geomorphic processes may be divided into constructive and destructive. Constructive forms of interest to petroleum geologists are dunes, barrier beaches, organic reefs, etc. Destructive processes create hills and valleys, underground drainage in carbonates, submarine canyons, etc., and create or destroy porosity by weathering.

The interpretation of buried landscapes presents many problems still unresolved among geomorphologists and also highlights several lesser known geomorphological phenomena. Subsurface data reveal that many landscapes exposed for millions of years were not peneplains but still showed considerable relief. The presence of well-developed slopes favors the theory of scarp retreat. Summit levels may also be related to contemporaneous erosional processes.

The solution of paleogeomorphological problems is greatly aided by applying quantitative geomorphological principles. The geological aspects of paleogeomorphology concern primarily the identification of erosion-resistant and less resistant horizons and the influence of structure (folding and faulting) on ancient drainage systems.

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Study of Foliate Structure in Molluscan Shells Indicating Specific Differences on the Generic Level

A general investigation of the molluscan shell microstructures within the Bivalvia (Pelecypoda) for the purposes of paleontologic and modern taxonomic studies indicated that it might be possible to differentiate skeletal structures on a lower level, generic, than was heretofore considered feasible. Since the crystals are the products of body chemistry secreted in closed systems, the crystals and (or) structures may mirror the difference in body chemistry between genera and perhaps species.

The foliate structure was chosen, and the genera *Crassostrea*, *Anomia*, *Placopecten*, and *Aequipecten* were compared by means of thin sections, peels, and a new technique with single crystals. The shells are disaggregated by removal of the binding organic matrix with EDA reflux and separation in an ultrasonic bath. All material was checked with the optical microscope and studied by carbon-platinum replicas and solid dispersions with Phillips EM 75C and EM 100B electron microscopes.

The foliate structure is produced by the aggregation in layers called folia of calcite crystals elongated along one of the a axes and flattened at the c. One parallel set of m and the $2c$ faces are dominant, resulting in lath-shape crystals. The c axis is normal to and the a parallel with the flattened folia surface and each of the crystals within one folia is oriented in the same sense.

In the disaggregate preparations, the crystals of *Anomia*, which are wider, longer, curved along the developed a axis and taper toward the ends, are easily recognized in the light microscope and differ markedly from *Crassostrea's* needle-like, short, straight crystals whose ends appear blunt. The crystals of the pectinid genera, though differing from both *Crassostrea* and *Anomia*, are similar in appearance and on the criteria used to date can not be differentiated.

The Carbon-Platinum replicas reveal surface features on the crystal surfaces, growth bands, parallel striations, etc. which may, with further investigation, prove of taxonomic value.

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Interpretation of Stratification

Ancient environments may be interpreted, at least in part, from primary structures in sedimentary rocks. Because such structures are largely developed during deposition, they provide information on the processes involved and on the general geologic and climatic setting. Unfortunately, many sedimentary structures are poorly understood; numerous data are required from the observation of modern sediments and of controlled experiments before positive conclusions can be drawn concerning rock genesis.

Principal types of stratification and cross stratification include (1) flat or horizontal bedding, (2) low-angle, simple or planar cross-stratification, (3) tabular-planar cross-stratification of intermediate angle, (4) high-angle, wedge-planar cross-stratification, (5) ripple lamination, (6) graded bedding, and other less common varieties. Some of these structures are typical of more than one environment; other structures are represented by two or more varieties in a single environment. Information on natural combinations or associations of these structures is especially valuable for paleoecological interpretations.

Environments of deposition that have been studied, in greater or lesser degree, with respect to the characteristic type or types of stratification are dunes, river channels, river floodplains, alluvial fans, delta cones, tidal flats, foreshore beaches, backshore beaches, and barrier bars. Very little information is yet available concerning primary structures representative of the various offshore marine environments.

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Foraminifers from the Eagle Ford-Austin Contact, Northeast Texas

Relations of the Eagle Ford shale and overlying Austin chalk (Turonian-Coniacian) have been of recurrent interest for many years. Since the work of L. W. Stephenson, the formations have been considered more or less disconformable in northeast Texas. This paper reports foraminiferal data that bear upon the question.

Samples were collected across well exposed contacts at thirteen localities that extend from Austin, Texas, in the south to Honey Grove, Texas, in the northeast, an outcrop distance of approximately 400 miles.

Samples from the Eagle Ford shale are marked by a paucity of specimens, a low number of species, extreme rarity of benthonic forms, and consequent dominance of planktonics which consist mainly of *Praeglobotruncana gautierensis*. Exceptions to the foregoing occur at the south in the vicinity of Austin, Texas, where foraminiferal number increases to about 25/gram and benthonic components remain essentially unchanged, and at the extreme north, relatively near-shore position, where benthonics become dominant but foraminiferal number remains very low.

Samples from the Austin chalk are marked by high number of specimens, high number of species, dominance of planktonics, and a quantitatively minor but comparatively striking and diverse benthonic fauna. Exceptions to the foregoing are infrequent and sporadic. *Lenticulina kansasensis* is widely present at the Austin base and can serve as a marker.

From consideration of the foraminifers and regional stratigraphy, it is inferred that uppermost Eagle Ford sediments were deposited on a deeper and somewhat toxic sea floor. Some information suggests that contemporaneous Austin-type sediments were accumulating upon an offshore bench or line of prominences. It is inferred that lowermost Austin sediments were deposited upon an offshore, relatively shallow and high-energy floor of likely high temperature and chlorinity.

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Pottsville Conglomerates in Pennsylvania: Paleocurrents and Origin

During Pottsvillean time, two major and strikingly different conglomerates were deposited in the northern part of the Central Appalachians. These are the Pottsville formation which crops out in the anthracite area and the Olean (Sharon) conglomerate which occurs along the northern escarpment of the Allegheny Plateau. The Olean (Sharon) is equivalent stratigraphically to only part of the thicker Pottsville formation.

An integrated stratigraphic, petrologic, and paleocurrent study was made of these conglomerates to reconstruct the clastic dispersal system, the geometry of the basin, and the conditions of deposition. Isopach, lithofacies, cross-bedding, maximum pebble size, and petrographic data were used to attain these objectives.

The depositional basin—an asymmetric, elongate trough which trends northeast-southwest—consists of (1) a narrow zone of maximum subsidence (trough) along its southeastern margin, and (2) a broad stable shelf area at the northwest. The basin was bounded on the southeast by a tectonic source land composed dominantly of metamorphic and sedimentary rocks and on the north by a stable cratonic area consisting largely of sedimentary and low-grade metamorphic rocks. Both areas contributed coarse gravels to the depositional basin.

A thick (up to 1,300 feet) wedge-shape conglomeratic sequence (Pottsville formation) was deposited along the southeastern margin of the basin by alluvial fans emerging from the southeastern highland. Initially, deposition was restricted to the trough area, where deposition was uninterrupted from the Mississippian to the Pennsylvanian, but later spread to the shelf. The transport direction was northwest (300–360°), transverse to the axis of the basin and down the paleoslope. The depositional strike paralleled the axis of the basin. The stratigraphic section thins downslope from the fall line, located near Philadelphia. This "tectonic" dispersal system deposited orthoquartzitic conglomerates and lithic sandstones (protoquartzites).

The thin (generally less than 50 feet) sheet-like conglomerate deposit (Olean-Sharon) along the stable northern margin of the basin was deposited by two contemporaneous fluvial systems, one located in north-central Pennsylvania, which dispersed material toward the southwest, and one in northeastern Ohio, which dispersed material toward the south. These systems transported material obliquely and parallel with the axis of the basin across an erosional Mississippian surface. These orthoquartzitic conglomerates and sandstones were deposited by the "cratonic" dispersal system.

In the central part of the basin, three sheet-like fluvial sand bodies (protoquartzite and orthoquartzite) were deposited. The lower Connoquenessing sandstone was deposited by the "cratonic" system; this sandstone and the Olean conglomerate appear to be part of the same rock stratigraphic unit. The upper Connoquenessing and Homewood sandstones were deposited by the "tectonic" system.

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Application of Diagenetic Principles to Petroleum Exploration

Investigations directed toward petroleum exploration problems have shown that diagenetic parameters can be useful in mapping subtle structural features that are not otherwise apparent. The investigations are based on the premise that structural movement alters the primary character of a sediment and that the degree and extent of alteration are a function of: (1) type of movement, (2) local intensity of stress, (3) age of movement with respect to reference horizons, and (4) the number of movements. Emphasis for exploration purposes is placed on (a) analysis of the alteration within the objective or reservoir horizon, and (b) interpretation of the structural history of the objective horizon in terms of stratigraphy, textural distribution patterns, and alteration in the overlying strata.

At numerous locations in the northern Rocky Mountains, anomalous textural distribution patterns in strata of different ages are superimposed on each other. These patterns reflect the recurring influence of structural movement in the same place at different periods in geologic time. Having defined these trends in broad terms of sedimentation, the local structural anomalies can be defined more precisely by analyzing the diagenetic changes; i.e., changes in cementation, grain and crystal alteration, solution characteristics, and fracture filling. These parameters show by the stratigraphic position of the alteration the influence of compaction, downwarp, upwarp, flexing, folding, incipient faulting, and truncation.

Calcite to dolomite conversions, as mineral cement in detrital rocks or as host material, offer the most apparent type of change as an indicator of structural deformation. Examples in the Williston basin are shown from Nesson and Cedar Creek anticlines, and also from the projection of the down-warped flexure related to the Van Norman fault. Other local areas along the northern limb of the basin are presented for appraisal.

Recrystallized and injected forms of anhydrite and halite are used as supplemental criteria because of their instability under stress. As deterrents to permeability, they receive special consideration when encountered in the objective horizon. Examples are cited from the Nesson-Frobisher and Midale facies in the northern Williston basin and from the Minnelusa formation of Wyoming.

Authigenic chert and quartz mosaics in the host rock and in fractures are used to help define faulted zones and unconformable contacts related to uplift and erosion. Examples are cited from the post-Mississippian–pre-Triassic surface of central Montana.

Results of these and other investigations show that alteration criteria can help to localize exploration prospects, and that some of the better known "stratigraphic traps" in the northern Rocky Mountains have had a recurring history of structural advantage over the surrounding area throughout much of geologic time.

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Aspects of Reef Development as Illustrated by the Devonian Ancient Wall Reef Complex, Alberta*

The Ancient Wall reef complex occurs in thrust sheets of the western Front Ranges of the Alberta Rocky Mountains north of Jasper. The reef complex is exposed

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