sources, accounting for about 60 per cent of our current research effort, are generally in terms of specific commodities. The lines of attack on these targets include district and regional geologic mapping projects and hydrologic studies, as well as related laboratory investigations.

In research aimed primarily at increasing our scientific knowledge, the geographic targets range from entire states or drainage basins to groups of a few quadrangles; topical targets are the understanding of a variety of fundamental geologic, oceanographic, and hydrologic principles and processes. These basic research projects, which account for about 40 per cent of the Survey's current research effort, include field studies as well as experimental investigations.

Our new long-range program, embarked upon this year, calls for expansion of our mapping and research activities approximately 70 per cent over the next 10 years. Some phases of this long-range program are not measurable in specific units because they are largely concerned with basic research, in which the achievement of one goal may beget several others; in these phases the level of effort is being increased to anticipate and meet the increased requirements that must come with the Nation's continued economic growth. Some finite goals of the more specific phases of the program are: (1) complete once-over topographic map coverage of the entire U. S. with standard 7½- or 15-minute quadrangles by 1976; (2) complete geologic map coverage at 1:250,000 by 1980, and at 1:62,500 by the year 2000; and (3) complete aeromagnetic coverage, at 1-mile spacing, by 1973.

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Pre-Maquoketa (Middle Ordovician) Cyclic Sediments in the Upper Mississippi Valley Area

Five cycles are recognized in the pre-Maquoketa (Middle Ordovician) marine strata of the Upper Mississippi Valley area: two in Cambrian rocks and three in Ordovician rocks. A sixth unit, at the base of this cyclic section, shows some cyclic characteristics, but is considered to be of non-marine origin.

A complete cycle includes the following units: Phase 4, carbonate deposits; Phase 3, fine-grained sandstone, fossiliferous, dolomitic, and glauconitic and (or) green shale; Phase 2, interbedded coarse-grained sandstone, locally conglomeratic, fossiliferous, dolomitic, and glauconitic, and poorly sorted sandstone composed of particles ranging in grain size from silt to coarse sand; Phase 1, orthoquartzitic sandstone deposits.

Analogous units in each cycle contain similar attributes of mineralogy, grain size, sorting, fossil content, sedimentary structures, contact relations, geometry, and lateral variations. The thickness of cyclic components may vary and components may be locally absent.

Cycles are believed to represent transgressive depositional environments caused by periodic rejuvenation of the land and inner shelf areas with contemporaneous activity in neighboring basins. Materials delivered to the shelf range in grain size from clay to granules. As land areas were worn down, sediments of Phase 1 accumulated on the shelf, building it upward. As the supply of sediment to the shelf decreased, wave and current energy was diverted toward reworking shelf deposits. Deposits of Phase 2 indicate alternating conditions of low and high energy which produced beds of well sorted coarse- and medium-grained sand alternating with poorly sorted beds of materials ranging in size from silt to granules. During Phase 1 and Phase 2 finer particles were kept in suspension. In Phase 3 these finer particles, together with those removed from shelf deposits during reworking, were deposited. Deposits of Phase 3 are fine-grained sandstone and (or) shale which are commonly dolomitic and glauconitic. Intraformational conglomerates are common. Phase 4 is characterized by carbonate deposition believed to have begun when energy conditions reduced sufficiently for the shelf bottom to stabilize and support life.

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Trace Elements in Recent and Fossil Mollusk Shells

Analyses were performed for iron, magnesium, manganese, strontium, barium, and mineralogy in the shells of seven species of mollusks collected over much of their present-day environmental range. Correlations between the shell composition and water temperature and salinity were determined in order to evaluate the feasibility of a paleoecological tool using these elements. Significant relationships were observed, but they are generally too weak to be used for paleoecological determinations and are not consistent between species. Differences in salinity cause greater changes in shell composition than differences in temperature, but salinities above 25 ppt. do not greatly affect the shell composition.

Unrecrystallized Miocene and Pleistocene shells of five of the same species were analyzed for comparison with the Recent shells. The average magnesium and manganese contents of the aragonitic fossil shells are lower, whereas the strontium, barium, and iron contents are higher than in Recent shells of the same species. The mean strontium and magnesium contents are lower in the fossil shells of the single calcitic species studied, and the remainder of the elements do not differ significantly. The difference in composition of fossil and Recent shells are attributed to post-depositional effects.

Paleoecological studies based on the composition of carbonate skeletons, radioactive disequilibrium age dating, and the oxygen isotope paleotemperature method should be used with the realization that changes in the trace element content of both aragonite and calcite can occur without recrystallization.

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Patterns of Flow and Channeling in Tidal Inlets

Tidal inlets penetrating narrow barriers and with or without tidal deltas typically have a central trough with terminal channel fans. The trough is centrally narrowly branched at each end with multiple, lesser, converging lateral channels. Deltaic sand, where present, tends to form peripheral shoals and shoals separating the two sets of channels. The trough is a narrow horizontal slot, ratio 1/24 to 1/75 in typical examples. Deep holes occur in axial and other narrows.

Detailed studies by others show that the individual channels of an inlet can usually be identified as either entering or issuing channels, subject to being shifted by longshore currents as the tidal phases change. Without further direct current studies, the gross flow characteristics of the channel systems may be interpreted from the described conditions. In both flood and ebb (rising and falling) phases, the water level is higher on one side of the barrier than the other. For the high sheet of water to get through the inlet, it must drain centripetally into it along all unobstructed radii, a *tidal drain*. The wide distribution of the minor lateral channels gives them most of the drainage.

The inlet flow issues with appreciable velocity scouring the trough and hole and forming a local maximum of current energy in its flow direction. The trough typically has two major branches at each end separated by shoals but narrowly and sub-centrally confined. If unobstructed and unbranched, the issuing channel flares like a horizontal jet, which ideally flares at 12°. Whether single or branched, the issuing current is a *tidal jet*.

Thus, at the ends of the inlet, both the flood and ebb tides are drains on the high side and jets on the low side of the barrier, in both cases being there local maxima of hydraulic energy.

The mouths of shallow estuaries, but not those of deep straits, show the type of channel pattern characteristic of the tidal inlet.

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RECENT CARBONATE SHOAL COMPLEXES IN NORTHERN BRITISH HONDURAS

In two separate areas on the continental shelf of British Honduras, the accumulation of Recent carbonate mud results in a series of mud shoals, herein termed mud shoal complexes. These shoal complexes range in depth from 1–5 feet and are dissected by tidal channels 6–10 feet deep. The tidal channels have slopes approximating 15° and divide each of the mud complexes into many individual mud mounds. The long axes of these mud mounds are essentially at right angles to the long axis of each mud shoal complex.

Both mud shoal complexes are represented by 7–9 feet of silt- and clay-size carbonate overlying a Pleistocene erosion surface. However, the mineralogical and biological characteristics of the two mud shoal complexes differ. With respect to mineralogy, one mud shoal complex, the Bulkhead, contains a lower percentage of aragonite and a higher percentage of low-magnesium carbonate in both the muds and adjacent sandy sediments than the Ambergris-Cangrejo mud shoal complex. With respect to biota, the Bulkhead shoal is characterized by a relative paucity of turtle grass, whereas the opposite is true for the other mud shoal complex. In the former case, mud deposition apparently results from the confluence of currents, the deposited mud being stabilized rapidly by the mucilagenous products of diatoms and other algae and less rapidly by the production of mucous-bound fecal pellets of worms. On the Ambergris-Cangrejo shoal, mud deposition and stabilization may be a product of the current-baffling and sediment-stabilizing attributes of the dense covering of turtle grass.

The mineralogical and biological differences between these two mud shoal complexes are not likely to be preserved in the geologic record. Inversion of aragonite and high-magnesium calcite to low-magnesium calcite, decay of plants, and possible dissolution of the opal tests of diatoms will undoubtedly occur during diagensis. Thus the tendency of diagenesis may be to reduce the lithologic and biologic distinctiveness of mud mounds of dissimilar origin. Consequently, the origin of similar-appearing ancient mud mounds may not be identical, and any theory of origin of any particular mud mound should be evaluated with respect to the source of the mud, the cause of local mud accumulation and stabilization, and the possible relation of the mound to a mud shoal complex.

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TRANSGRESSIONS AND REGRESSIONS IN THE GULF COAST TERTIARY

In the central and western Gulf Coast the Tertiary, whose maximum thickness at any one place is probably about 30,000 feet, consists almost entirely of alternating marine and non-marine fine-grained terrigenous clastics. Some of the marine formations extend to the outcrop, but many others are now deeply buried and are represented in the outcrop by non-marine deposits. All formations grade eastward into shallow marine carbonates.

Numerous local and many regional transgressive and regressive sequences of sediment are present. The local fluctuations in the strandline were caused by delta building and abandonment; the regional shifts are believed to have been caused by variation in the rate of subsidence of the basin or to variation in the amount of sediment transported to the area. It appears that sedimentation was faster during the regressive periods than during transgressions. However, the progradation was in most cases slower than the movement inland (transgression) of the sea.

The generalized sedimentation history of the Tertiary in the central and western Gulf Coast is explained. The only rhythmic or cyclic sedimentation patterns in this thick section are a result of shifting strandlines which may have no relation to eustatic changes in sea-level.

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EVOLUTION AND DISPERSAL OF THE EARLY PERMIAN FUSULINID GENERA *Pseudoschwagerina* AND *Paraschwagerina*

Two genera of fusulinids, *Pseudoschwagerina* and *Paraschwagerina*, long recognized as stratigraphic guides to Lower Permian beds, contain more than 100 species which can be grouped according to their morphological similarities and differences into twelve phylogenetic lineages. The primitive species complexes that initiated these lineages began near the beginning of the Permian in the Western Hemisphere. Their widespread migration and subsequent restriction led to the evolution of more advanced lineages of which several had times of widespread, but commonly brief, distribution.

The most primitive pseudo-schwagerinid complex, the *Pseudoschwagerina beedei* complex, arose from inflated *Triticites* ancestors probably in the Andean geosyncline. This complex gave rise to the *P. uddeni* complex, which attained both Eurasian and Western Hemisphere distribution, and the *P. d'orbignyi* complex which is known from South America and southern Europe. The *P. heritschi*, *P. carniolica*, and *P. miharanoensis* complexes are largely restricted to Eurasia or to small areas of the Eurasian fusulinid province. The ancestors of each of these three complexes are poorly known but they apparently arose from advanced species in the *P. uddeni* lineage. Both the *P. yabei* and *P. stanislavi* lineages appeared very late in the evolution of the genus. The *P. yabei* complex ranges into strata of Leonardian age in southern Europe and Asia and the *P. stanislavi* complex occurs in strata of Leonardian age in Eurasia and North America.

The most primitive paraschwagerinid species complex, the *Paraschwagerina gigantea* complex, is apparently related to the genus *Schwagerina* but its ancestry is not well known and species of *Schwagerina* that would form typical ancestors for *Paraschwagerina* did not evolve until *Paraschwagerina* itself was nearly extinct. Of the younger and more advanced complexes, the *P. plena*