

Major observations from this study are: (1) what is interpreted as the base of the nearshore ridge directly overlies skeletal rich sediments, whereas what is interpreted as the base of the middle shelf ridge directly overlies sediments without skeletal remains; (2) skeletal rich and nonskeletal lithologies are present in the relief-forming portions of the ridges; and (3) the upper unit, the "upper ridge sand," is generally similar in character on both ridges.

ROBERTS, HARRY H., and STEPHEN P. MURRAY, Louisiana State Univ., Baton Rouge, LA

#### Gulfs of Northern Red Sea: Depositional Settings of Distinct Siliciclastic-Carbonate Interfaces

The two narrow gulfs of the northern Red Sea, Gulf of Suez and Gulf of Eilat (Aqaba), have had different tectonic histories, but both display active interfingering of siliciclastic and carbonate facies. In an early stage of rifting, these embryonic seas are flanked by rugged mountains (about 2,000 m, 6,500 ft) and narrow coastal plains built of fans composed of poorly sorted terrigenous debris. An arid setting promotes aperiodic transport of siliciclastic sediments as well as deposition of evaporites (coastal sabkhas) and carbonates (reefs and associated sediments). Gulf margins prograde by a combination of rapid fan deposition during flash floods and subsequent carbonate stabilization of terrigenous fans and cones during intervening periods. High-resolution seismic and side-scan sonar data suggest that narrow pathways for sediment transport are continually active on these features and probably accommodate much of the sediment transport to deep water during small discharge events. Large flash floods may completely overwash carbonates at the distal ends of fans, requiring renewed reef development. Rapid siliciclastic deposition, coupled with biological and chemical binding of carbonates as well as their tendency toward vertical buildups, results in steep slopes along the gulf margins.

The Gulf of Suez is shallow (< 100 m, 330 ft), and a relatively broad (> 12 km, 7.5 mi) and geometrically complicated strait separates it from the northern Red Sea. In contrast, the Gulf of Eilat is deep (< 1,800 m, 5,900 ft) and has a very narrow strait. Although both basins result from rifting associated with opening of the Red Sea, the Gulf of Suez is dominated by normal faults and tilted blocks, whereas the Gulf of Eilat formed primarily by strike-slip displacements with minor movements perpendicular to its extension. Seismic and borehole data confirm that the Gulf of Suez is a graben-like structure that has filled with nearly 6 km (20,000 ft) of dominantly siliciclastic sediment since Miocene times. An evaporite unit over 1-km (3,300-ft) thick and numerous thin carbonate horizons as well as local reef buildups interfinger with the noncarbonates. Over 3 km (9,800 ft) of sediment fill has been confirmed from the Gulf of Eilat, but a base for the sequence has not been identified. Turbidites and pelagic deposits fill the deepest basins.

The Gulf of Suez contains numerous carbonate platforms seated on subtle gulf-parallel structures. Some of these carbonate build-ups suggest that they are the initial stages of much larger carbonate platforms that will develop as rifting continues. Modern physical processes—strong axial winds (< 30 m/sec, 100 ft/sec), an energetic gulf-parallel wave field, and vigorous tidal currents (> 50 cm/sec, 20 in./sec)—tend to streamline reefs and sediment bodies, creating spindle-shaped carbonate platforms. The Gulf of Eilat has no mid-gulf platforms, but a complex of reef-dominated carbonates exists on gulf-normal structural blocks at the Strait of Tiran. A cross section reduction of this already narrow strait by lowering of sea level, reef growth, and/

or sedimentation could drastically change the basin-filling process through restricted flow by eliminating reef growth and initiating salt deposition.

ROBINSON, GARY C., FERNAND BAIXAS, and PATRICK J. HOOYMAN, CGG, Denver, CO

#### A Three-Dimensional Seismic Survey Applied to Field Development in Williston Basin

The Medicine Lake field of Sheridan County, Montana, was discovered in March 1979. In October 1981, a mini-3-D seismic survey covering 2.5 mi<sup>2</sup> (6.2 km<sup>2</sup>) was acquired over this field in order to facilitate development drilling by delineating the field's reservoirs and obtaining a more accurate image of the subsurface structure.

A multiline system, consisting of 240 geophone groups distributed on 8 lines, was used. The energy source was shothole dynamite using 5 lbs (2.3 kg) charges at 250 ft (46 m). The shotpoints were arranged in a cross pattern with extra shotpoints included to provide necessary control on the weathered zone. The average subsurface coverage was 600%, with CDP bins 165 ft (50 m) square. Prior to the actual shooting, a computer simulation of the resulting fold was performed to verify the field geometry. The entire survey was recorded in one day with no movement of the geophones, thus minimizing costs.

The data volume was processed in preserved amplitude through 3-D migration and 1-D inversion. The subsurface image was substantially improved by the 3-D migration process. The advantages of this enhanced focusing ability are particularly important when attempting to delineate the lateral extent of reservoirs and detect lithologic variations.

The Medicine Lake field is located on a structural high, although there are stratigraphic implications for several of the producing zones. The interpretation of the data therefore focused on both structural and stratigraphic features.

The Medicine Lake structure is prominently displayed on the Winnipeg event, showing a closure in excess of 180 ft (55 m). Several reflectors near the base of the Red River interval terminated against the Winnipeg event, indicating that this structure was a high in Red River time. Discontinuities in the Cambrian and Precambrian reflectors suggest that the Medicine Lake structure is a result of basement faulting.

The objective of the stratigraphic interpretation was to outline zones of possible porosity, particularly in the Madison and Red River intervals. The horizontal and vertical inverted sections were particularly useful for ascertaining the location and lateral extent of those anomalous zones. The results correlate well with known production, and should aid in the location of future development wells.

ROBINSON, J. E., Syracuse Univ., Syracuse, NY

#### Computer Analysis of Early Well Logs

Geophysical well logs have been recorded in wells drilled for petroleum and natural gas since the early 1930s. These, largely hard-copy records, comprise the greatest pool of factual subsurface information on producing reservoirs and on new prospects that were either not economic or overlooked when the wells were drilled originally. As such, they are a valuable exploration tool but are difficult to use because of the incompatibility of recorded information both within and between wells.

Early well logs display a wide range of curve types with a

remarkable variety of calibration and depth scales. Visual analysis with well-to-well continuity is almost impossible with the logs in their original form. Fortunately, the hard-copy logs can be digitized and computer-processed to produce standardized logs that are amenable to accurate analysis for contained hydrocarbons and the spatial mapping of potential reservoirs.

The process does require the services of a petroleum geologist to determine the log response to clean formations within each well. However, once the individual curve parameters are determined, the computer can carry out the detailed computations for the display and isolation of all potential reservoirs. Examples of logs from New York state indicate that many gas-bearing reservoirs remain to be exploited.

ROBISON, VAUGHN D., Univ. Oklahoma, Norman, OK and UWE TRÖEGER, Technical Univ. Berlin, Federal Republic of Germany

#### Geology and Organic Geochemistry of Dakla Shale, Egypt

The Dakla Formation is late Campanian to Paleocene in age and, in eastern Egypt, is overlain by the Nubian Sandstone and underlain by the phosphate-bearing Duwi Formation. Lithologically, samples of the Dakla shale member collected in the Red Sea area consist of marls to marly clays, range from brown to black in color, and are bounded at the top and bottom by phosphate-bearing strata. Organic carbon and extractable  $C_{15+}$  hydrocarbon concentrations for samples from Quseir, Hamrawein, and Safaga ranged from 3.8 to 5.9%  $C_{org}$  and 550 to 2,400 ppm HC, and may be petroleum source rocks in areas where burial and thermal conditions are adequate. Shale samples from the Quseir region yielded Fischer assay results of 40 gal/ton, and thus have considerable potential as oil shales.

Samples from the Sibaiya region in the Nile Valley are light to dark gray shale and average 0.2%  $C_{org}$ . In this area, the phosphate deposits associated with the Dakla Formation are presently being exploited.

The Dakla shale samples from the Abu Tartur region, in the Western Desert, contain organic carbon concentrations in excess of 4.0%. Such values are considered suitable for potential petroleum source rocks where other conditions are satisfied. Recent exploration activity in the Western Desert region may make petroleum source rock studies of the Dakla shales increasingly important.

RODRIGUEZ, ARGENIS, Univ. Toronto, Toronto, Ontario, Canada

#### Coal Occurrence and Characteristics as Related to Environment of Deposition in Cerro Negro Area of Orinoco Tar Sands, Venezuela

Sedimentological analysis of cores taken in the Cerro Negro area of the Orinoco Tar Sands have provided lithological, textural, mineralogical, and paleontological data which have enabled facies identification. These facies have been interpreted as belonging from an upper delta plain to a semi-restricted shallow marine environment of deposition. Coal beds occur in all the wells analyzed. These occurrences are closely associated with specific facies, such as the back-barrier lagoonal facies of the semi-restricted environment of deposition and the backswamp facies of the delta plain. More importantly these coal beds present very distinguishable characteristics, such as variation in thickness from few inches in the back-barrier facies to 5 ft (1.5 m) in the delta plain facies. Their organic composition also ranges from

micrite/atrinite to vitrinite and exinite in different proportions. Therefore, it is believed that variations in thickness and perhaps in organic composition are related to facies changes.

ROEDER, DIETRICH, Anschutz Corp., Denver, CO

#### Style Zonation in Fold-Thrust Belts

All orogens have thick-skinned and thin-skinned-style provinces. Thick-skinned belts form in a variety of crustal settings common in upper plates of Andean-type orogens and in both plates of aging collisional orogens. Thin-skinned belts specifically require transport at one transcrustal sole thrust. In collision belts, the sole thrust is the suture. In belts antithetic to Andean-type subduction, the sole thrust departs upward from the point of the asthenospheric wedge.

Arrays of strike belts with different styles signal the thin-skinned scenario and its distortion in thick-skinned settings. A proposed zonation includes the following. (1) Detached fold belt with 1 to 5 km (0.6 to 3 mi) deep sole sloping at 0 to 2°, without topographic slope, and with strain increasing coreward to 80%. (2) Imbricate belt with 3 to 10 km (1.8 to 6 mi) deep sole sloping at 1.5 to 3.5°, and with bulk strain increasing to 100% or more. (3) Allochthonous belt consisting of polyphase (typical: thick-skinned pre-transport strain) crust and cover rocks above a sub-thrust sediment complex showing 100 to 500% strain. Base of subthrust complex is 5 to 20 km (3 to 12 mi) deep and slopes at 3 to 15°. (4) Root zone with polyphase and progressive strain, steep dips, retrocharriage, and late shallow detachment. (5) Late stage thick-skinned structures including foreland upthrusts, massifs (Helvetic and Penninic), and core complexes (cordilleran) occur anywhere between root zone and foreland. Their detachment, rise, and transport distort the thin-skinned features but cause more thin-skinned detachment in the external belts.

Presence and width of strike belts and their style elements (e.g. folds, ramps, imbrications, back thrusts) can be explained as interplay between gravity spreading and thrust loading of an elastic foreland crust. Style-determining factors include (1) time spent within thrust wedge, (2) rigidity of foreland crust, (3) topographic slope, and (4) distribution of competent and incompetent rock units.

Polyphase kinematic sequences reflect the numerical divergence between the elastic foreland wedge and the transport requirement of "optimum taper;" we distinguish polyphase wedge thickening and fold-discordant wedge transport.

Seismic work and drilling in all five zones provide the data base for the zonation. Hydrocarbons are produced from all zones except zone 3. Conventional production comes from zones 1, 2, and 5. Most ongoing overthrust plays are made in zone 2. Zone 3 has potential where the allochthon is thin (such as ophiolites or detached shelf sediments), where the foreland sediment series is complete (as in collision belts), and where collision is too recent for thermal stabilization.

ROSS, CHARLES A., Gulf Oil Exploration and Production, Houston, TX

#### Late Paleozoic Foraminifera as Depth Indicators

Many late Paleozoic foraminifera consistently occur in particular rock types for which depths of deposition may be inferred. A few genera appear randomly in many different rock types and were possibly pelagic.

Textulariina: In the Ammodiscacea, most genera of Hippocrepininae (Astrorhizidae) and Ammodiscidae are widespread and