DIPMETER MANUAL

AND EXERCISES

Dipmeter Interpretation Rules

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Part stratigrapher, part petroleum geologist, and part sedimentologist, the dipmeter interpreter peers down boreholes to figure out, among other things, which way the wind blew at a given time — 2 or 5 or 8 million years ago. Knowing which way the wind blew helps tell which way oil flows and, ultimately, where the drill bit goes. Simple. But not so simple.

To discern details as fine as wind direction, the dipmeter interpreter examines stratigraphic information from a number of wells. The interpreter moves back and forth from the big picture to the small picture, adjusting one then the other to shape the optimum three-dimensional picture of a certain horizon at a certain time. Gilreath starts with the depositional environment constrained to two or three possibilities. He first addresses the big picture: Are we in a delta? A stream bed? A barrier island? A reef? Subsequent questions examine one corner of the big picture: If we're in a delta, what part? If we're in a stream bed, exactly where? If we're in a barrier island, are we on the seaward side or the landward side? Finally, the last questions fine-tune the stratigraphic interpretation: Which way the wind blew, the currents flowed, the tides ebbed and flooded, and what each means to the shape, character, and extent of rock bodies. Addressing these last questions ultimately determines strategies for the exploration, drilling, and production of oil and gas.

Summed up, Gilreath's interpretation scheme has four steps:

- Limit likely depositional environments based on client's knowledge or key logs (e.g., bound water and shale resistivities and dip scatter).
- Determine gross structural dip and delete it if necessary.
- Ascribe missing and repeat sections to unconformities or faults (see page xx).
- Using knowledge of dip, structure, lithology and depositional environment, make a stratigraphic interpretation, which includes an estimate of the shape and extent of reservoir rock. Examples in this supplement summarize this final step.

Method of Plotting

The tadpole plot is the traditional graphic device used on dipmeter logs. It gives three pieces of information: (1) the lateral position of the tadpole head represents dip magnitude, which increases to the right from 0 degrees to 90 degrees; (2) the tail projects from the head in the downdip direction; (3) and the vertical position of the head indicates depth. The top of the plot is north.

Dips are grouped into four color-coded patterns:

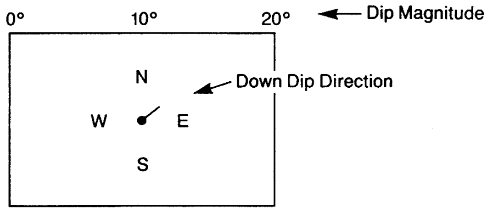
Blue indicates dips decreasing downward.

Red indicates dips increasing downward.

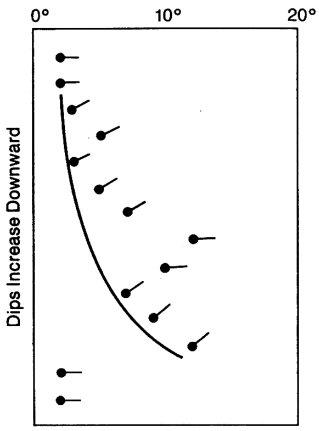
Green indicates no change in dip with depth. This is usually taken to indicate structural dip, the tilting imposed on the rock by tectonic forces.

Yellow is assigned to random dips.

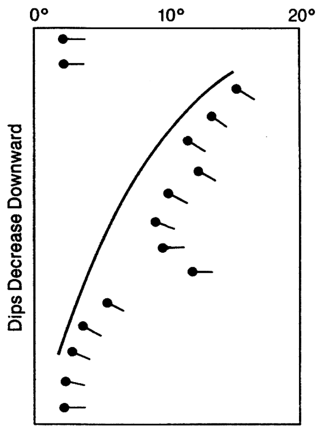
Since different stratigraphic features can create the same dip patterns, it is important to limit the depositional environment before keying a dip pattern to a stratigraphic feature. The meanings of various dip patterns in the context of different depositional environments are shown in the following series of theoretical dip versus lithology patterns for common depositional environments. Each log is discussed from the bottom up.



Example 10° N 45°E



Red Pattern



Blue Pattern

Green Pattern — Dips constant with depth

Yellow Pattern — Random dips

Nonmarine/Continental

The four structural (green) dip patterns indicate sediments deposited essentially flat in an upper delta plain. (You can expect sands in such an environment to have secondary porosity from plant-produced acids that have dissolved sand grains.)

The yellow "bag-of-nails" pattern near the bottom results from disturbed bedding from high-energy surges in the flood plain. You'll be able to discern few, if any, structural dips in such environments.

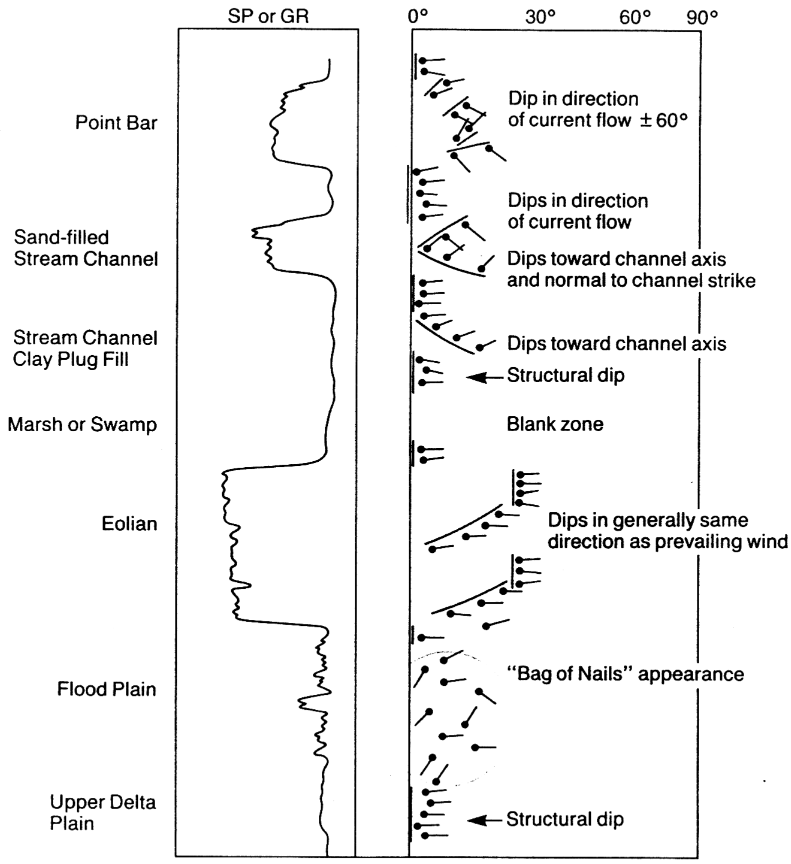
Moving up again, the green over blue patterns are characteristic of eolian dunes, especially transverse and barchan. The wind blew toward the downdip direction (west to east). Dome and parabolic dunes produce mainly red patterns, also with the wind blowing downdip. Longitudinal dunes produce red or blue patterns with dip direction normal to prevailing wind direction.

Blank zones result from destruction of bedding planes from bioturbation and rooting, indicating marsh or swamp deposits.

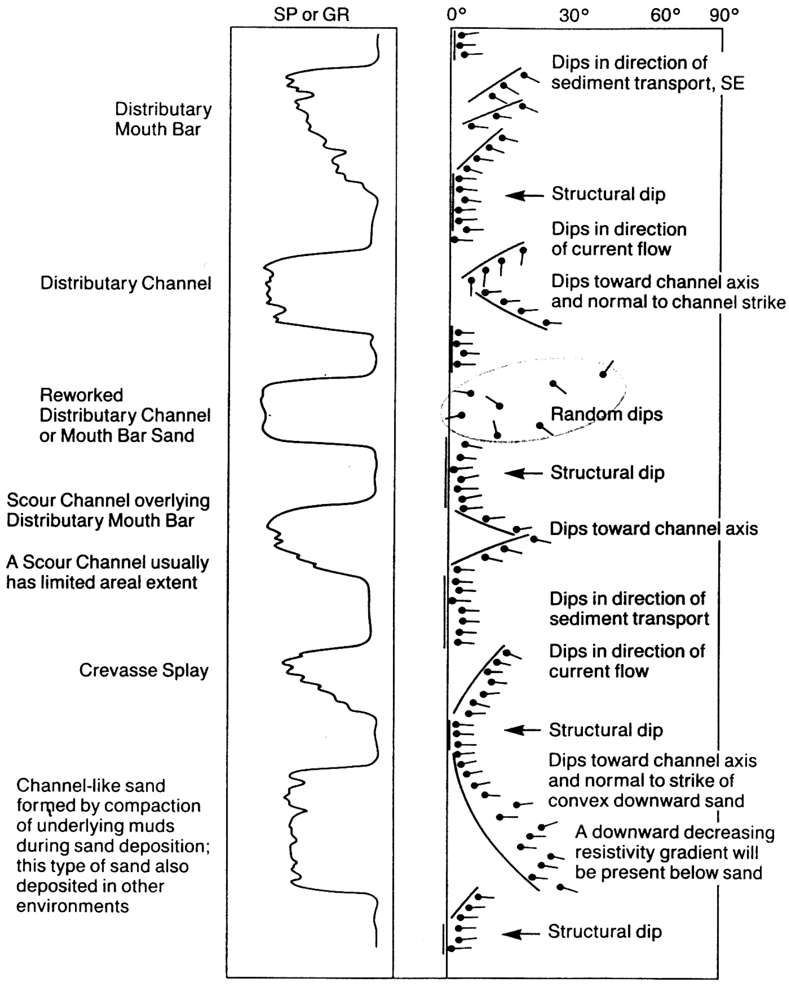
Red dip patterns within shale zones (indicated on the spontaneous potential or gamma-ray [SP/GR] curve) suggest clay-filled stream channels. The downdip direction is toward the thalweg.

The blue over red pattern, with the blue dipping normal to the red, and the SP/GR curve indicating sand, suggests a stream channel. The red dips are normal to channel strike (northwest-southeast). Flow direction is downdip of the blue pattern (to the southeast).

Several blue patterns at the top of the log are typical of point bar sands, when core and other geological studies indicate a fluvial environment. These dips are in the direction of current flow ±60 degrees. If the patterns extend more than 3 feet, they probably result from accretion deposits, which dip toward the thalweg, rather than from trough cross-bedding, in which they would dip down current.



Continental Shelf: Delta Dominated



The sudden decrease in the SP/GR log is of limited use here, but coupled with an increase in the resistivity log (not shown) it would indicate compaction of a mud, probably by an overlying sand. The long, sweeping red pattern suggests a channel-like sand. The red dips are normal to the axis of the sand. Such sands can be more than 2,000 feet thick.

Moving up, the blue patterns can indicate either a crevasse splay or a distributary point bar. The saw-tooth SP/GR curve, indicating pulses of deposition, is not much help, since it is associated with many features. Resorting to information from other wells can be helpful and often necessary to distinguish crevasse splays from distributary points bars. Sands limited in areal extent suggest a crevasse splay; extensive sands suggest a distributary mouth bar. In this example, current flow is downdip (southeast). The underlying structural dip (green) probably indicates that the splay or bar formed over a flat-lying delta outwash plain.

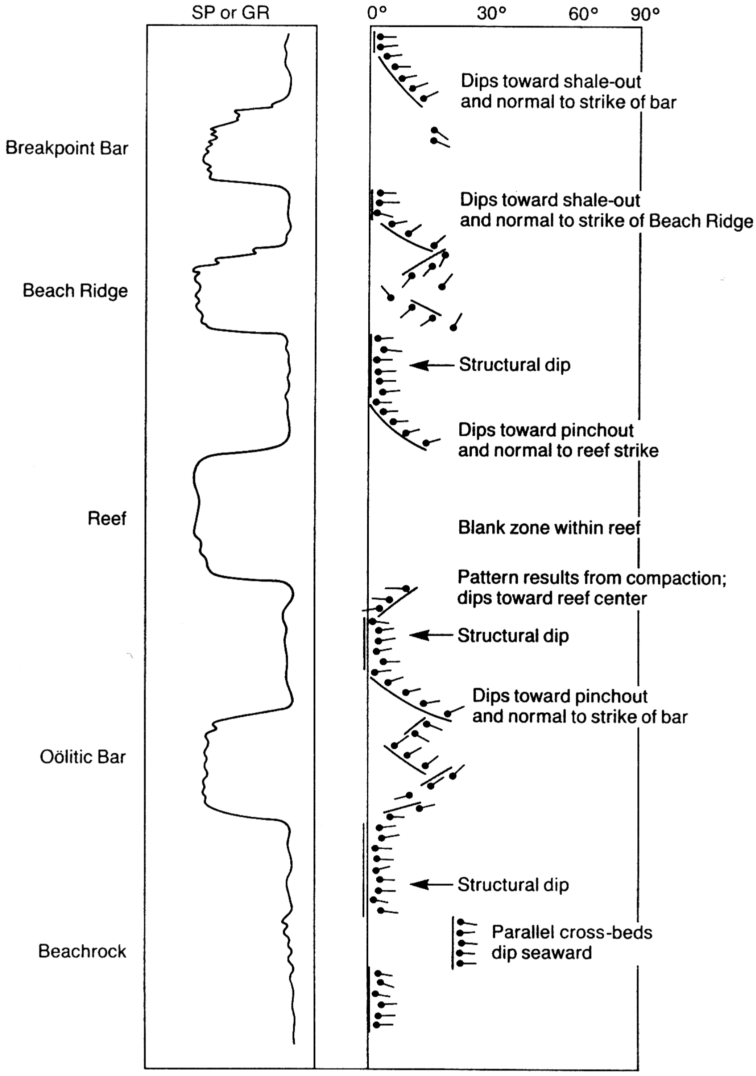
Red over blue patterns dipping in parallel are characteristic of a distributary mouth bar sand topped by a scour channel. The blue patterns, which result from foreset bed deposition, dip in the direction of current flow (to the east-southeast) and the red patterns, which result from drape over the base of the channel, dip toward the scour channel axis (east-southeast).

The overlying yellow pattern could have a few causes, but is most likely a reworked distributary channel or mouth bar sands, since it is sandwiched between channel deposits. These sands tend to be clean, with good permeabilities and porosities.

The red pattern (from drape) overlain by a blue pattern (from foreset beds) dipping normal to it suggests a distributary channel. The red pattern dips toward the channel axis, and the blue pattern dips downstream (south).

The topmost feature was identified as a distributary mouth bar based on studies in other wells. Based on the dipmeter plot alone, the bar is indistinguishable from a crevasse splay. The multiwell study, however, permitted mapping a channel. It was logical to conclude that the blue patterns at what seemed to be the end of the channel must indicate a distributary mouth bar. In general, blue patterns dipping away from the channel axis indicate crevasse splays; blue patterns dipping parallel to channel strike are due to a distributary mouth bar. Variation in dip magnitude gives some indication about the shape of the distributary mouth bar. When dip varies 10 degrees or more, the bar tends to be elongate downdip. When dip varies less than 10 degrees, the bar tends to be crescent- or fan-shaped.

Continental Shelf: Tide, Wave, and Current Dominated (1)



Stratigraphic features of this environment are often the result of reworking of previously deposited deltaic sediments.

The two green patterns at bottom are interpreted as parallel cross-beds dipping seaward about 20 degrees. Existing knowledge of the area's lithology, based on cores or density and neutron logs, established this as a carbonate zone. The parallel cross-bedding could be from an eolian feature, but it probably indicates beachrock, a carbonate that forms at the saltwater–freshwater interface along the shoreline.

The red pattern, produced by drape, overlying the blue pattern, produced by cross-bedding, indicates a bar identified by the client as oolitic. The pinch-out is downdip (northeast) and the strike of the bar is normal to dip (northwest–southeast). Dips within the bar are irrelevant. The key sign of a bar or reef is a red pattern, which indicates a convex upward feature, above a permeable zone. A blue pattern, indicating a convex downward feature, above a permeable zone would suggest a channel-like feature.

The next zone shows more characteristics of a reef: a blank zone — caused by massive, nonbedded reef material — over a blue pattern, caused by mud compaction, and under a red pattern, caused by drape over the reef flank. The red patterns dip toward the pinch-out (east–northeast) and normal to the strike of the reef (north–northwest by south–southeast). The blue pattern, which results from compaction, dips toward the thickest part of the reef.

The next set of red patterns overlying numerous dips at odd angles suggests a buried beach ridge. Beach ridges typically have dips in many directions, as opposed to bar deposits, which tend to have uniform dips from reworking by waves. The red patterns indicate the top of the ridge and the numerous dips indicate the ridge's interior. The red patterns dip toward the shale-out (northeast) and normal to the strike of the beach (northwest–southeast).

Finally, the uppermost red pattern overlying two dips normal to the general red trend suggests a sand bar that formed at the wave break point. The homogeneity of the dips is strong evidence for reworking, a characteristic of breakpoint bars. The red pattern dips toward shale-out (northeast) and normal to the strike of the bar (northwest–southeast). Breakpoint bars can be distinguished from longshore current sand waves in that the former are usually overlain by a red pattern, and the latter have blue patterns within the sand. Dips in both can be seaward or landward.

Continental Shelf: Tide, Wave, and Current Dominated (2)

Based on knowledge that the well intersects a beach, the bottommost blue pattern, sandwiched between green patterns, indicates a slip face sand on the landward side of the beach. The blue dips point landward (west) and are normal to the beach strike (north–south).

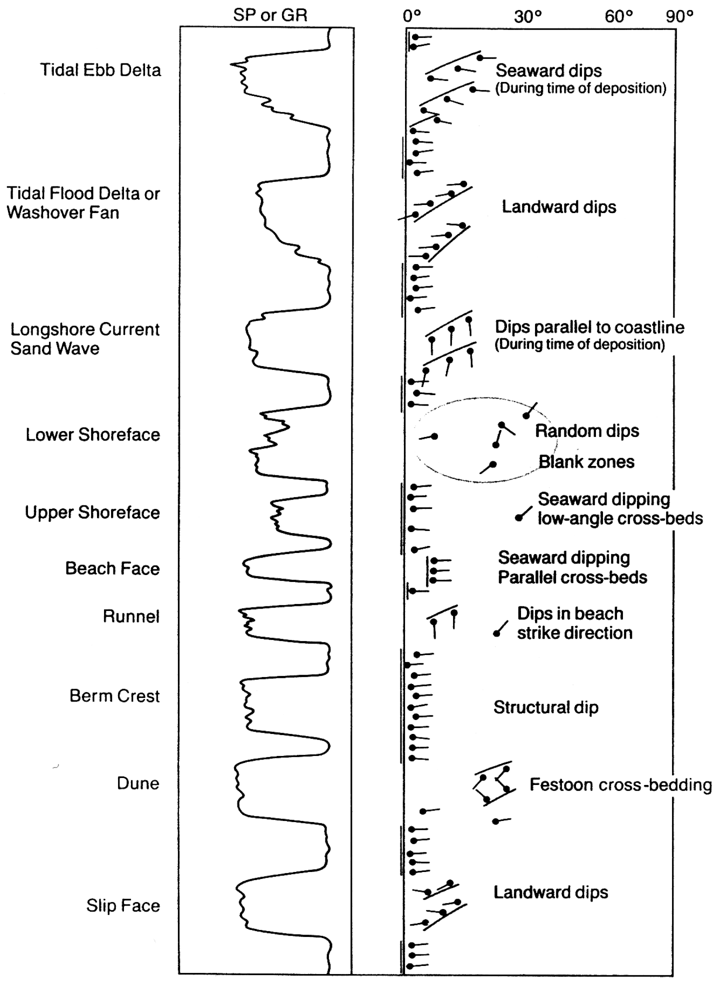
Again, based on knowledge of a beach environment, the collection above of varying blue patterns with dips landward indicates festoon cross-bedding. This type of a bedding is common in primary dunes, the first row behind the beachface, and is caused by variations in wind direction. The overlying green pattern probably indicates a berm.

The few overlying random dips overlain by a blue pattern suggests a runnel: the blue pattern derives from megaripples and the random dips are from small-scale ripples. (Small-scale ripples can also produce blank zones.) The dip of the megaripples parallels the strike of the beach (north–south).

Above the runnel, green patterns of varying dip magnitude suggest parallel cross-bedding in beachface sands. Since the sea was downdip of the cross-bedding, at the time of deposition it lay to the east. The flatter lying sands above suggest the lower energy environment of the upper shoreface sands. The random dips above suggest the high energy and bioturbation of the lower shoreface. This area can also be indicated by a blank zone.

Blue patterns overlying green suggest longshore current sand waves overlying a fossil shoreline, given knowledge of a silicate shore. The blue patterns dip in the direction of longshore transport (from north to south) and parallel the shoreline strike (north–south).

Landward dipping blue patterns indicate landward sediment transport, probably produced by a tidal flood delta or a washover fan. The overlying seaward dipping blue pattern suggests a tidal ebb delta.

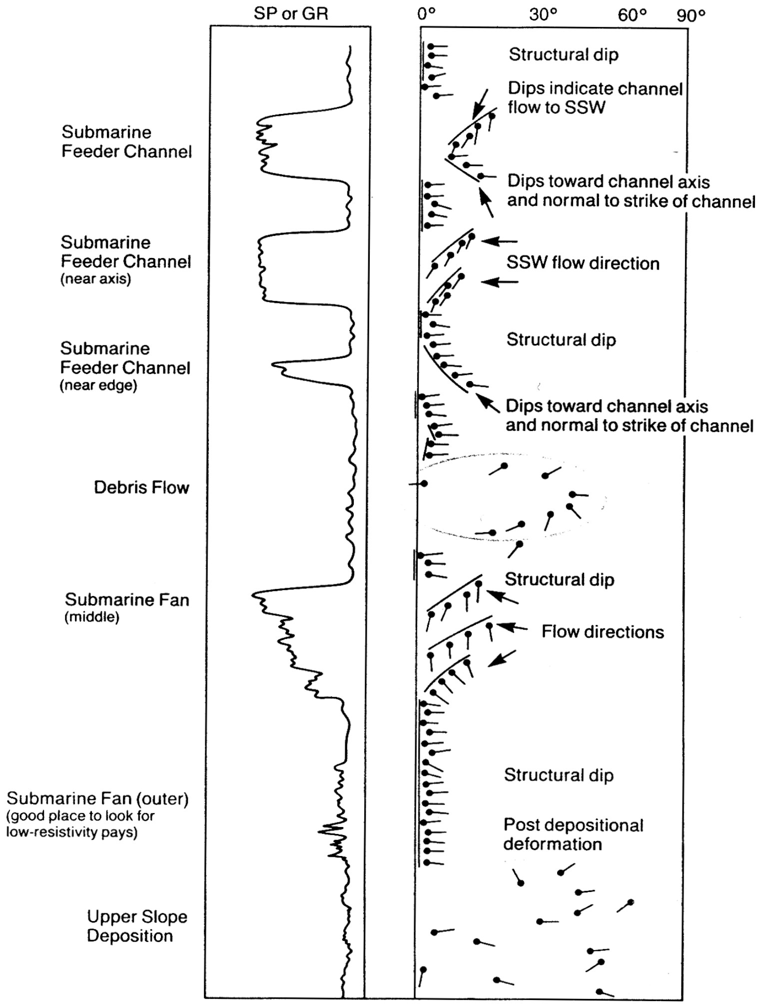


Continental Slope and Abyssal

Sediments in the deep waters of the continental slope and beyond often undergo post-depositional movement that produces random dips. Structural dip, consequently, is difficult to determine in these environments. Dips that appear to be structural can indicate the most common flat-lying features — submarine fans and feeder channels.

Reading the log from the bottom, the yellow pattern suggests either a debris flow or upper slope deposits that were deformed after deposition. Distinguishing between the two requires data from a core or a Formation MicroScanner* (FMS) log. Above them, the structural dip and evidence in the SP/GR log of alternating sand/shale layers suggest the low-lying outer edge of a submarine fan. Farther up, the appearance of blue patterns from cross-bedding suggests either the axis of a feeder channel or the mid-fan. Mid-fan deposits, however, are much more common. Sediment transport is in the downdip direction of the blue pattern (north to south).

Independent information from cores indicated this second yellow pattern results from highly deformed sediments, probably from a debris flow. The following patterns suggest the various parts of a submarine feeder channel. Red indicates the edge of the channel, with the dip toward the channel axis (axis to the east) and normal to channel strike (north–south). The two blue patterns above suggest the channel axis, with transport direction downdip (toward south–southwest). Finally, the blue over red patterns, with dips 90 degrees apart, indicate an area of the channel between the axis and the edge. The red pattern, again, dips toward the channel axis and normal to channel strike, and the downdip direction of the blue pattern indicates the transport direction. The decline in SP/GR values with depth in the mid-fan suggests the sand is getting coarser with depth. This occurs because the first deposits of a fan are the finest, then, as the fan builds out, coarser sediments are carried farther. Finally, the uppermost layer, which was nearest shore, will be the coarsest. The numerous SP/GR excursions in the outer fan indicate alternating sand-shale layers.



* Mark of Schlumberger