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Sedimentary Aspects of the New River Delta, Salton Sea, Imperial County, California

ABSTRACT: Located at the southern end of the Salton Sea in Imperial County, California, the New River Delta has a subaqueous extent greater than 25 km^2. The accumulating deltaic sediments are supplied by the New River at a rate of 500 x 10^6 kg suspended sediment annually. New River drains 6,500 km^2 over its 150 km length.

Because of its unusually small size, the New River Delta provides an excellent model for a detailed analysis of deltaic facies distribution and relationships. Subaerial deposits comprising distributary channel, levee, interdistributary subaerial flat and crevasse deposits are the most varied. Subaqueous deposits are largely prodelta clay and delta-front fine silt.

Sediment size distribution is related to distributary patterns. Sand and coarse silt characterize distributary channel and proximal delta front environments. Lateral gradations from sand to clay or sand to interbedded silt and clay are common as one moves from distributary channels to interdistributary areas. Vertically, basal prodelta clays grade upward into silty delta front facies which either are overlain by interdistributary and marsh clays and silts, or by sands of distributary channels.

Sediment mineralogy reflects the composition of its source material—Colorado Delta detritus. Organic carbon is characteristically high (5%, maximum) in fine marsh clays, mudflat, and prodelta clays and low in delta front and distributary coarse silts and sand (0.58% minimum).

Climatic factors exert considerable control on deltaic configuration and the subaerial extent of the New River Delta has been severely reduced by rising water levels. The delta has accumulated sediment at an average rate of slightly over 1 cm/yr for the past 66 years. When the total volume of sediment in the delta, 0.024 km^3, is compared with river discharge, it is apparent that most of the sediment is trapped by the delta.

Factors common to most modern deltaic masses such as abundant plant remains, high mica content, elongate sand bodies, highly organic prodeltaic deposits, and laminated sands over muds can be used in recognition of ancient deltas. All of these features are manifest in the facies of the New River Delta and indicate that similar balances between sediment input and local energy levels will produce similar sedimentary patterns regardless of scale.

INTRODUCTION

The New River Delta, located at the southern end of the Salton Sea, Imperial County, California (see Figure 1) is the product of the catastrophic flooding of the Salton Sink by the Colorado River in 1905-1906. The delta in 1972 had a subaerial length of approximately 3 km and widths ranging from a few hundred meters to 2 km. The total area of influence is about 25 km^2.

Because the valley has been an important agricultural area since the beginning of this century, the water levels, rates of evaporation and water budget of the sea and its tributary streams have been recorded in detail. As a result, the history of the factors affecting delta development are known for the entire period of deposition. The delta provides a scale model of deltaic processes in an area unaffected by tides and with low wave energy. The study was initiated in order to determine the sedimentologic similarity or difference between this small feature and the equivalent lobes produced by single depositional cycles in large deltas of major rivers. If the small delta is similar to the large ones, then the results of contemporary investigations can be extrapolated to identify ancient deltas with confidence that the differences in scale of individual deltas will not affect the resulting characteristic assemblages of facies.

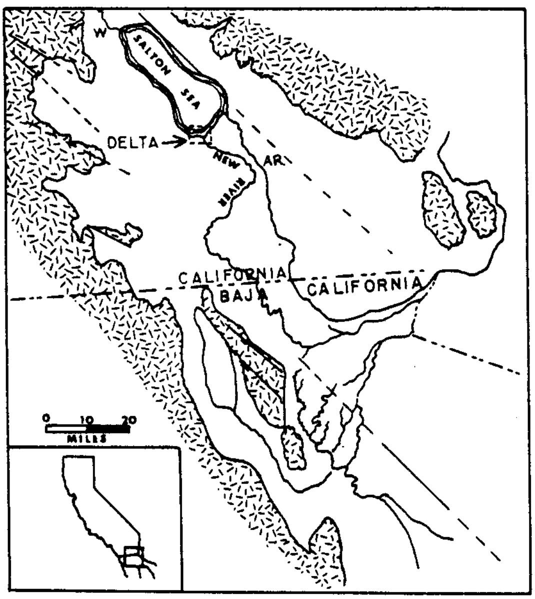

Figure 1. Location map of the New River Delta and drainage area (after Dibblee, 1954). Alamo River (AR) and Whitewater River (W) also drain into the Salton Sea.

History of the Salton Sea

The geologic record shows that the Colorado River has alternately deposited its load into the northern and southern portions of the great structural trough of which the Salton Sink and the Gulf of California are part (Buwalda and Stanton, 1930; Dibblee, 1954; Allison, 1964; Biehler et al., 1964; Walker, 1967). More recent students of the area (see in Henyey and Bischoff, 1973) have shown that this entire structural province is intimately related to the movement of the North American and North Pacific crustal plates in middle to late Tertiary time.

Although much remains to be done in precise research, the sediments of the upper Gulf of California adjacent to the Colorado Delta record changing rates and sources of sediments that must be a product of recent shifts in the Colorado River's course (Byrne and Emery, 1960; Van Andel, 1964; Thompson, 1968). Work is in progress by Bischoff and Henyey on the chemical evidence from cores in the northern Gulf that will aid in documenting the late changes.

Arnal (1961) has shown that the record of changing salinity following the formation of the Salton Sea can be read in the characteristics of the microfaunal assemblages in the modern sediments.

Blake (1854) reiterated Indian accounts of great floods which forced tribes to flee the valley floor and move up into the surrounding mountains. A few radiocarbon dates for calcareous lake deposits (R. H. Merriam, personal communication) indicate that a lake filled the basin as recently as 700 years ago. However, no mention of any lake was made by explorers (Kino, 1701, as cited in Byrne and Emery, 1960).

The agricultural value of the southern Imperial Valley, referred to as the Salton Sink before 1905, was recognized as early as the 1850's by Blake (1854). But not until 1900 was work begun to irrigate the basin using water diverted from the Colorado River (see in Brown, 1923; Sykes, 1937). Inasmuch as the Colorado River had sent its flood waters over its banks and into the Salton Sink for many years along the New River and Alamo River channels (Chase, 1919), it was felt diversion could be accomplished easily, especially because the natural gradient into the Salton Basin is greater than toward the Gulf of California. An artificial gap was excavated into the levees of the main river channel to lead water by canals to the Basin. Brown (1923, p. 11) notes:

> "Several unusual floods that occurred in the spring of 1905 greatly widened the arti-

ficial breach in the river bank made to admit extra water into the canals. These floods also carried out the dams built to seal off this inlet...During the high water season of this year, much water flowed through the canal and over its banks and wasted into the basin at the bottom of the Salton Sink, where it formed the beginning of the present Salton Sea...Strenuous efforts were made to dam up the intakes, but flood followed flood, and one after another the structures were carried away.

The Salton Sea grew day by day...as the whole flow of the Colorado River was pouring through an opening now hundreds of feet wide. The water on its way...ate great canyons in the soft silt of the valley. These canyons are followed by the present channels of the New and Alamo Rivers."

The breach was finally closed in November, 1906, and the history of the New River Delta starts from that date. Local records of water flow and suspended sediment discharge have been maintained virtually from the date of initiation.

Physiography and Climate

Situated in a huge northwest-trending topographic and structural depression, and flanked by faults in the San Andreas zone, the Salton Sink's surface elevation is approximately 85 m below sea level. The depression is bounded on the north and west by the Peninsular Ranges which include the San Jacinto, Santa Rosa, Vallecito, and Laguna Mountains. To the east of the basin are the Little San Bernardino, Orocopia, and Chocolate Mountains. The southern boundary is the Colorado River Delta which separates the valley from the Gulf of California. The trough itself is filled with over 6000 m of clastic sediments derived primarily from the Colorado River drainage as well as from the adjacent mountains.

Drainage is toward the present Salton Sea which occupies the lowest section of the Salton Basin. The Salton Sea receives water from a total drainage area of 21,800 km^2 (Anon., 1970), principally from three major rivers, the New River, Alamo River and the Whitewater River (Figure 1). Numerous small streams discharge directly into the sea and 3600×10^6 m^3 a year of water is imported by canals for irrigation (Anon., 1970). Average subsurface flow into the Salton Sea is estimated to be 60×10^6 m^3 a year. Surface of the lake in 1970 was about 70 m below sea level, and maximum depth was about 15 m.

The land surrounding the lake exhibits the typical physiographic features associated with arid regions. Huge alluvial fans spread out from the surrounding mountains, sand dunes occur in the northern areas and along the western margin of the lake. Badlands carved in soft clays and sandstones of the Mecca and Indio hills are present along the borders of the basin. Arroyos dissect the surrounding desert flats. Vegetation is sparse.

Temperature, precipitation, and evaporation values for the Salton Sea region are characteristic of mid-latitude deserts. Of these, the most significant to our study are the rainfall and evaporation rates.

Rainfall ranges between a maximum monthly value of 17 mm precipitation in December to a trace recorded in June. Average annual rainfall over a 73-year period is 81 mm.

Evaporation at a rate of about 1780 mm per year (Blaney, 1955) is recorded with a maximum at Indio of 422 mm for the month of July.

New River Location, Length and Discharge

The Imperial Canal, which branches from the Colorado River, and the Paredones River are tributaries of the New River at its initiation along a natural divide on the Colorado River Delta. Volcano Lake, also located on the divide, yields intermittent flow to the New River. Flowing directly northward for 140 km (Anon., 1908) from its Mexican headwaters, the New River drains part of the Mexicale valley in Mexico, crosses the International Boundary, and flows through the southern Imperial valley. Ultimately the river empties into the Salton Sea, the largest inland body of water in California. The drainage area (approximately 650 km^2) and route traversed by the river are depicted on Figure 1. Flow is well-regulated owing to an extensive irrigation canal system which maintains flow even during dry seasons. River discharge ranges from 10 m^3/sec to 30 m^3/sec with an average of about 20 m^3/sec.

DELTA CONFIGURATION AND GROWTH RATE

Factors Influencing Delta Formation

After the flood flows of 1905 through 1908, New River discharge was low until 1918. A rapid but steady increase in discharge occurred between 1918 and 1924 (Figure 2). This increase corresponds with agricultural development in the basin and resulting increase in irrigation return waters. Discharge since has been erratic in detail, but shows a gradual increase over the last 45 years. Sediment contribution parallels discharge.

Hydraulic coastal processes in the Salton Sea exert very little influence on delta morphology. Wave energy is extremely low and as a result, there is no extensive reworking of sediments, only minor erosion on the delta. Wave-driven longshore currents are negligible. The Salton Sea is devoid of tidal effects as well. Arnal (1961) measured wind-driven circulation patterns in the Salton Sea. Dominant eastern winds drive water south along the western margins of the sea. When the water reaches the southwestern part of the sea, west winds direct the currents east and north along the eastern margin of the sea setting up a counterclockwise gyre. This gyre deflects fresh water flow from the New River and causes the depositional features to trend to the east. Subsidence and structural effects are negligible.

The most effective control on growth and configuration of the New River Delta has been climate. Extreme evaporation rates cause seasonal fluctuations in lake level. Initially (Figure 2) the level of the lake was at its highest elevation immediately following the floods which formed the lake (1906). Intense evaporation and low stream discharge resulted in the sharp fall of the lake surface until 1920 when it became stabilized

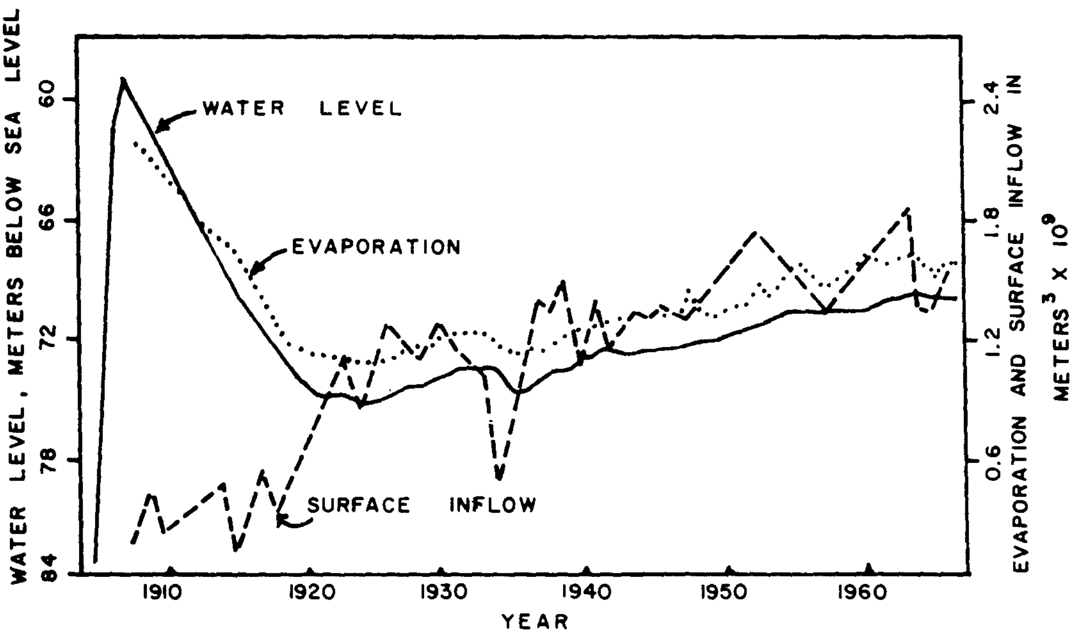

Figure 2. Evaporation, surface inflow, and water levels for the Salton Sea. Data from California Department of Water Resources Bulletin 143-7.

with the inflow of runoff and irrigation discharge. There have been several small but rapid increases since then; increases occurred during intervals in 1938 to 1940, 1950 to 1954, and again in 1962. These rises in lake level had marked effects on delta configuration.

New River Delta Development

Initial deltaic deposits were described by Sykes (1937, p. 70) as follows:

"Upon entering the steeper grades which existed as the Sink was approached, its (the New River) competence for ablation was correspondingly increased. This together with the friable nature of the material over which inflow was taking place caused some spectacular recessive cutting. The peak discharge entering the fast growing "Sea" by way of the New River was about 70,000 second-feet. The total yardage removed and transported by the New and Alamo Rivers within a period of a few weeks was roughly computed at 400,000,000 cubic yards.

"The whole body of this detrital matter was quickly redeposited in and under the rapidly increasing waters of the lake in the form of the foreset beds of a true delta. Little or no subaerial deposition took place . . . By 1915 the lake level had fallen about 30 feet and the shore line had receded more than 6 miles at the southern end, where the inflow had taken place at the high water stage. The material brought in by the two streams united to form one general deposit while the lake level was rising, but by 1915 the medial lines of their deltas were over 6 miles apart. An examination . . . during the spring of 1915 showed the delta forming process still in action. The New River delta being larger and increasing . . . rapidly."

The delta continued to develop and artificial levees were constructed to direct the flow of water and control deposition of sediment. After the gradual rise in lake level from 1950 to 1954, the delta's configuration was only slightly altered. In Figure 3, the delta configuration in September, 1954 is illustrated.

In 1954 the delta covered 20 to 25 km^2, a much greater expanse subaerially than at present. At this time, sediment was transported away from the elbow bend in the New River at the southeastern corner of the delta (lower right hand corner of Figure 3) along three primary distributary channels. The largest volume of sediment was transported northward along the most active main distributary which split to generate two distributary lobes or dispersal centers. A small fan-shaped lobe formed where most of the sediment discharged to the east producing the plumes of turbid sediment-laden water seen in Figure 3. An intricate vein-like network of distributary channels on this lobe also can be clearly discerned. A somewhat larger and more diffuse lobe was being built farther north and directly out from the main distributary channel. Moving 45° counterclockwise on the photo from the main north-south distributary is the second primary distributary network. This second network consists of a tree-lined artificial levee system with several north-south artificial levees extending north from the main northwest channel seen on Figure 3 as a long straight diagonal.

Carrying sediment into an embayment in the southern corner formed by the artificial levee network is a third distributary channel that flows west then south from the elbow of the New River. This dispersal system consists of a winding distributary channel which bifurcates to form a broad interdistributary plain.

Because of the complex formed by the three primary distributary networks, many inlets and embayments were available to trap fine clay in quiet water. Undoubtedly mud flat deposits were quite extensive at this stage of deltaic development.

With the subsequent rise of lake level in 1962, much of the delta in Figure 3 was submerged and the drastic change in configuration which occurred can be seen when Figure 4, an airphoto taken in 1965, is compared with Figure 3. Both figures are to the same scale.

Only one-third to one-half of the delta remained exposed. During this period, distributary systems on the south and western margins of the delta were abandoned. The submerged trees of the artificial levee system provided a quiet inlet allowing the large mud flat to fill the area as shown on Figure 4.

Sediment dispersal shifted and was limited to the northern and eastern margins of the delta. Turbid plumes extend north and eastward from the active distributary channels. Turbid water also is trapped north of the mudflats and results from discharge through small channels along the western edge of the main distributary channel.

Rate of Delta Growth

Utilizing data from 41 piston cores collected for this study (Figure 5), the depth to various

Figure 3. Aerial photograph of the New River Delta showing its nature and extent in 1954. Note the three distributary systems active at this time, and the extent of the delta.

facies was determined and an isopach map constructed of total sediment thickness for the present exposed delta. Since the delta was built over red alluvial clays that are compact and relatively impermeable, a readily identifiable basement is thus provided. The isopach map (Figure 6) is the basis for determining the volume of sediment in the exposed and immediately adjacent subaqueous deltaic sediments. These calculations yield a conservative estimate of 12×10^6 m^3 for the total volume of sediment in the present subaerial delta. Assuming a density of 1.5 g/cm^3 for the sediment in conjunction with this volume of 12×10^6 m^3, the total weight of this wedge of sediment is found to be approximately equal to 18×10^9 kg. However, since the aerial photograph of Figure 3 shows the subaerial extent of the delta in 1954 to be at least twice its present

Figure 4. Aerial photograph taken in 1965 of the New River Delta. The reduction of surficial extent and change in sediment dispersal patterns are easily discerned when this photograph is compared to Figure 3.

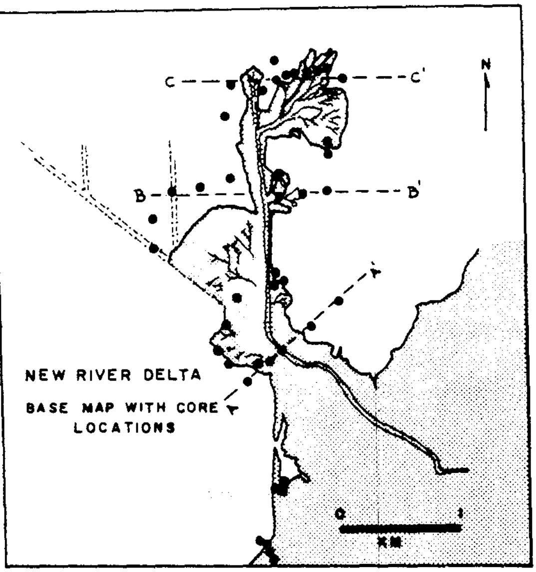

Figure 5. New River Delta base map with core locations (black dots) and profile lines for Figure 12.

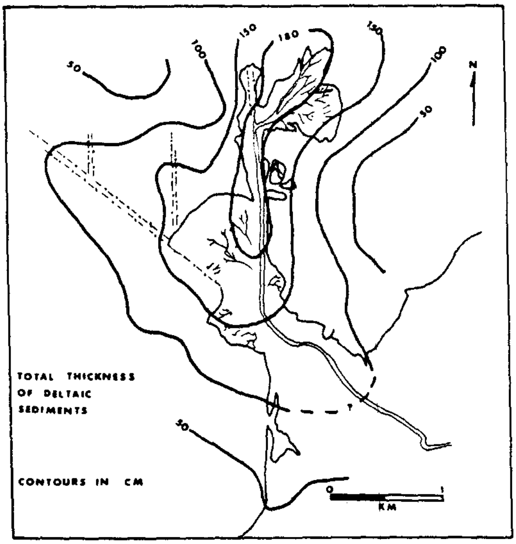

Figure 6. Isopach map showing total thickness of deltaic sediments. Greatest thickness is along primary distributary outlets while minimum thickness is at distal areas along the outer and lateral delta perimeter.

extent, it is clear that the total volume and weight of all the deltaic sediments must be based on this total subaerial and subaqueous area. Thus, a value of 36 x 10^9 kg total weight is not unreasonable (based on a total area of 25 km^2).

Daily suspended sediment discharge over the past 20 years has been recorded by the Imperial Irrigation District. From their records, the average annual suspended sediment discharge for the New River is 500 x 10^6 kg. Assuming an 80:20 ratio between suspended sediment discharge and bedload from estimates of the sand in the delta, there is a resultant total sediment load discharge of perhaps 600 x 10^6 kg a year. The total weight, 36 x 10^9 kg, when divided by the annual discharge, 600 x 10^6 kg yields a value of 60 years, which is close to the age of the delta, 66 years. This appears to verify our estimate of total area. If the sediment discharges were lower at some time earlier in the delta's history than the 600 x 10^6 kg annual average for the last 20 years, then the time calculated for deposition would be greater, but this seems unlikely. As shown in Figure 2, discharge is variable but was abnormally low during the interval from 1910 to 1920. This low flow period would extend the length of time required to build the present delta by a small amount, but in any event, the close match between estimate and actual age is indicative that this low flow period was minor in effect.

Sedimentation rates for the delta must certainly be quite variable and for any specific area are a function of proximity to the distributary channels. Several long cores (180 cm) were recovered and rates of 3 cm/yr would be required to deposit the sediment at these locations. In contrast, other areas received little or no sediment. To calculate an average sedimentation rate for the entire delta, divide the volume by the area of 25 km^2 and this simple division provides an average sedimentation rate of slightly over 1 cm per year for the entire delta.

Based on these figures, it is apparent that most of the sediment discharge of the New River is effectively trapped by the delta and only minor quantities of material escape to be deposited on the floor of the Salton Sea.

Surface Morphology

The New River is a relatively small river with moderate discharge, depositing its sedimentary load into a shallow and quiet body of water in an arid region. A map of the exposed subaerial and subaqueous environments which developed under these conditions can be seen in Figure 7. The New River delta plain consists of the main river channel and flanking levee and crevasse deposits. The western half of the delta, now devoid of active distributaries, is a combination of abandoned distributary and interdistributary environments and mudflats. The mudflats are now filling an embayment between the present New River channel and an old distributary channel whose presence can be traced by a submerged tree line. Active sedimentation is concentrated at the north-eastern end of the delta in a lobate distributary plain. South of this major lobe and on the eastern side of the river channel are several small crevasse-type deposits that now receive flow through conduits placed in the levee to prevent further breakouts and to maintain discharge at the outer northern delta periphery.

Surrounding the subaerial deltaic plain are subaqueous prodelta clays. Subaqueous lobate silt and coarse silt delta front sediments extend from distributary mouths and overlie prodeltaic clays.

Subaqueous Environments

Located off the mouth of distributary channels are lobate sheets of coarse silt which are distributary-controlled delta front sediments. This type of deposit is often referred to as distributary mouth bars (Kolb and Van Lopik, 1966; Kanes, 1970; Donaldson et al., 1970; Gould, 1970). Typically low in organic carbon, the sediments are comprised of coarse silt and often exhibit ripple structures. Plant debris and wood chip fragments are commonly interbedded or scattered in these deposits.

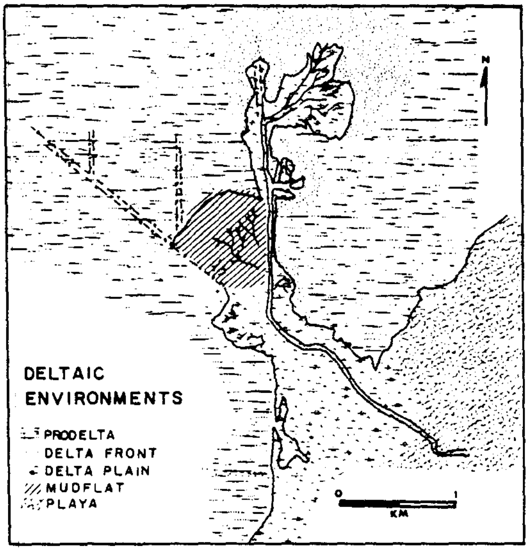

Figure 7. Surface extent of deltaic environments.

Surrounding the subaerial and delta front environments are the prodeltaic clays deposited in the quiet waters on the outer perimeter of the delta. Such clays are often laminated and contain relatively high amounts of organic carbon. Their color varies with depth but the upper surface typically is black. Sediments in this environment are also of high water-content and are oozes down to a depth of 30 cm or more. Prodeltaic clays described by Shepard (1956, 1960), Scruton (1960), and Kolb and Van Lopik (1966) are the first terrigenous sediments introduced by an advancing delta and form a platform upon which the surficial delta front and subaerial environments rest.

Subaerial Environments

The levees are the most prominent topographic features of the delta coupled with the lush vegetation which they support. Consisting primarily of dredged deltaic sediments, tree stumps and rock, the levees were built to maintain the present delta configuration.

The main distributary is confined by the artificial levees shown in Figure 9. Sediments in this distributary channel are current-rippled fine sands and exhibit cross-bedding in section views. These channel sediments are generally well-sorted with low organic carbon content, characteristics controlled by current action. Overall distribution of surface sediments is shown in Figure 8.

Vegetation is dense and 1 to 1.5 m in height at this locality on the outer margin of the main distributary lobe. On the photograph notice the absence of surface cracks in the silt and fine sand in the axis of the abandoned channel. Sediments on the interdistributary flats are typically clay or clay silt with intermediate to high organic carbon values.

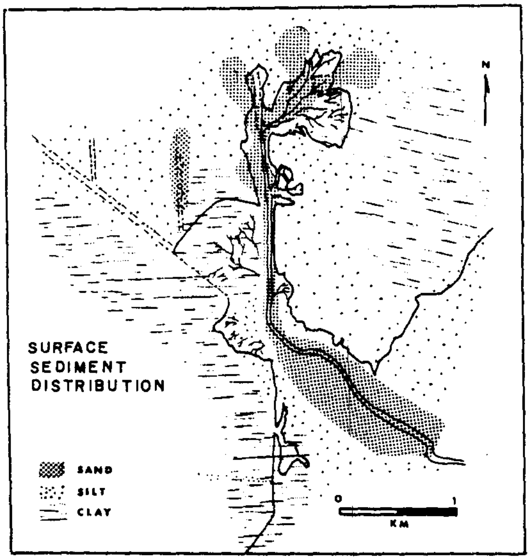

Figure 8. Areal distribution of sediments in terms of major size classes.

Figure 9. View north on active distributary lobe, where complex distributary patterns are evident. This illustration was taken at lowest water level late in the summer. Surface is entirely flooded through late fall, winter, and spring.

On the main distributary lobe the channel bifurcates into many smaller distributary channels. Photographed at a low lake level during summer, 1971, Figure 9 shows the multiple subsidiary channels in the distributary floor. Characteristically, these channels consist of fine sand or coarse silt with low organic carbon values and are the major factor controlling sand deposition and distribution on the delta.

Between the complex of major distributary channels is the interdistributary environment which includes subaerial flats and abandoned distributary channels. Also present are flats similar to the washout pans described by Kanes (1970) on which either thin algal mats or algae crusts are dominant. Characteristic interdistributary subaerial flats and abandoned distributary configuration is pictured in Figure 10.

Figure 10. Abandoned distributary channel on outer margin of main distributary lobe. Notice absence of surface cracks in silt and fine sands along channel axis. This surface is flooded and received sediment in both winter and spring months.

Second only to the primary distributary lobe in extent are mudflat deposits in small inlets on the distributary lobe or in embayments between abandoned distributary channels. These mudflat deposits are fine-grained clay, characteristically high in organic carbon. They also have extremely high water-content and are unconsolidated to depths of 1.5 m or more. One can literally drown if not careful because these sediments have no bearing capacity and one sinks rapidly in them. Such flats support a varied fauna, primarily worms and snails upon which birds feed. These muds are rich in gas (in part H_2S) which escapes when the sediments are disturbed. Kolb and Van Lopik (1966) observed that mudflats occur when the influx of fluvially-introduced clays predominates over beach-forming processes along a shoreline. Such is the case on the New River Delta where these deposits are typically protected either by submerged levees or lie in embayments formed by deltaic sedimentation and are consequently protected from wave attack.

Crevasse deposits like those described by Russell and Russell (1939) occur along the eastern flanks of the delta. Formed by deposition after a break occurs in the levee, these deposits are characteristically comprised of sheets of coarse silt and fine sand, and are low in organic carbon. They overlie the clays of the quiet embayment on the eastern side of the delta and are currently active owing to conduits placed under the artificial levee to prevent further levee erosion.

Another prominent feature which occurs on the northern delta perimeter are beach ridges (Figure 11). They are peculiar in that they consist entirely of whole and fragmented barnacle shells. The barnacle shells behave hydraulically as sand grains and are tossed up by storms and held by shrub stalks at the outer edges of the delta.

Water levels fluctuate seasonally in the Salton Sea; shoals and flats are exposed during the hot summer months. In December, the water is 20-25 cm deeper. As a result of this fluctuation and exposure of shoal areas to the desert heat, huge dessication cracks form in clay-size sediments. The cracks often extend to a depth of 10-15 cm and are commonly filled with sediment when flooding occurs in late fall. Another result of the seasonal fall of lake level is a series of regressive shorelines which develop on interdistributary clay-silt material.

Figure 11. View of wave-built barnacle beach ridges. Storm waves pick up and concentrate barnacles on exposed northern end of delta.

Sedimentary Structures

To document sedimentary structures, all cores were x-radiographed using procedures outlined by Bouma (1969). Certain environments tend to have structural characteristics which in conjunction with other parameters might aid in interpretation of ancient deltas (see Table 1). Major associations are similar to those of the larger deltas.

Distributary channel sediments are characteristically cross-bedded and in their lower parts may contain scattered plant debris. These cross-bedded sands interfinger with interdistributary subaerial flat deposits. Structural features common to such clay and clay-silt sediments are mudcracks, plant debris layers, mottling, burrows, and irregular or lensoid laminations. Occasionally present are interbeds of silt and clay. Mudflat or inlet deposits are mottled clays in which burrows and irregular laminations commonly occur. Crevasse deposits generally exhibit parallel sand and silt laminations alternating with

Table 1. NEW RIVER DELTA SEDIMENTARY STRUCTURES

Environment	Structures	Sediment	Geometry
Distributary channel	small scale, tangential, and planar cross-beds; trough cross-beds; plant debris layers	fine sand	linear sand bodies which interfinger with interdistributary deposits, occasionally interbedded with interdistributary deposits.
Interdistributary subaerial flat	fining upward sequence; burrowed laminated clays; mud cracks; root disruption; filled mudcracks; burrows; gas pockets; interbedded clay, plant debris, and sandy silt	sandy silt, silt, and clay	irregular to lobate—occur in association with distributaries
Mud flats	bioturbated, mottled, gas pockets, burrowed, massive	clay	irregular pockets occur in sheltered embayments
Delta front	interbedded sandy silts and plant debris	fine sand and sandy silt	lobate sheets
Prodelta	massive and laminated	clay	basal platform

clays. Plant fragments, current ripples, cross-bedding and erosional truncations occur intermittently. Shoals and seasonally exposed flats are mudcracked, generally burrowed, and laminated. Mottling occurs occasionally.

Delta front sediments are thin, cross-laminated coarse silts which contain scattered plant debris layers. These silts are often interbedded with clay-silt layers which commonly exhibit burrows or bioturbation effects. Prodelta clays range from thinly laminated clays to massive homogeneous clays near the bottom of this sequence.

Delta Structure

The New River Delta resembles the minor distributary systems of the Mississippi Delta which develop in areas marginal to a main stream and are called shoal water deltas (Fisk, 1961). Shoal water deltas are formed when sand, carried to the mouth of an enlarging pass, forms a bar that divides the stream into branches, each of which lengthens and bifurcates to form a part of a complicated branchwork. In these branches, sands are deposited which interfinger with adjacent clay and silt deposits and grade both laterally and vertically from coarse to finer materials.

New River facies interrelationships are depicted by section diagrams in Figure 12. These sections were constructed using data obtained from the cores which are located on each section.

Sections A-A′ and B-B′ are similar in that each has a basal layer of prodeltaic clays, overlain by delta front clay silts and silts. The delta front sediments are overlain by large wedges of fine sand and coarse silt which are river channel deposits. Both sections show a very deep and U-shaped sand finger along the main channel. When the Salton Sea formed, the New River channel incised itself deeply into the soft sediments of the previous playa surface creating a natural crevasse which the delta sediments filled before spreading laterally. Note that there is

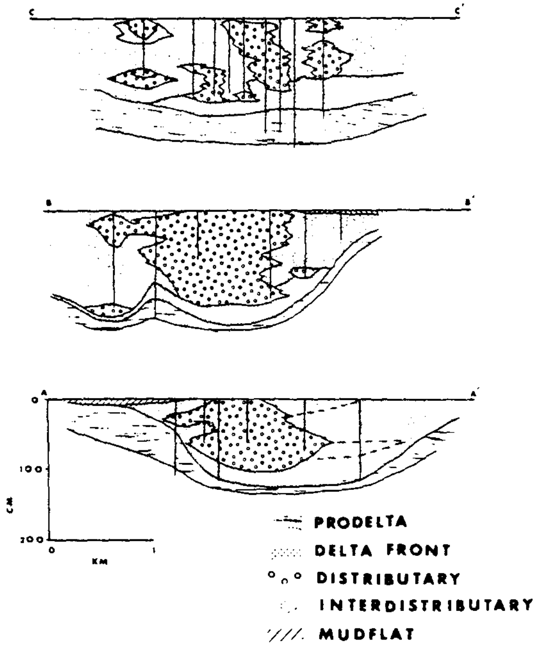

Figure 12. Section A-A′, southwest to northeast, delineates the configuration of vertical sediment distribution across the main delta distributary channel. Section B-B′, east-west, displays vertical sediment distribution across the main distributary channel farther north than A-A′. Deposits such as mudflats which flank the channel are of note. Section C-C′, west to east, delineates the vertical distribution of facies at a point on the main distributary lobe where the primary distributary channel has bifurcated to form smaller but more numerous distributary outlets which interfinger marsh and interdistributary deposits. Locations of sections shown on Figure 5.

considerable exaggeration in vertical scale. The central trough or finger of sandy material grades laterally into marsh and interdistributary deposits of silt and clay.

Section C-C′ was made across the main distributary lobe of the delta and depicts the complicated distribution of facies with depth at this locality. The large sand channel of Sections A-A′ and B-B′ has now separated into numerous distributary channel fingers which are enveloped in silty clay material of interdistributary, marsh, and delta front origin. Sands of this type are comparable to those described as bar finger sands by Fisk (1961).

Bates (1953) reported that the density of the receiving sedimentary basin waters have a marked effect on current patterns at the mouth of the stream and hence on the area of deposition of the suspended load. The New River Delta is extending into the Salton Sea which has a salinity that approximates that of sea water. Under existing conditions, stream flow will not mix but will rather tend to spread out horizontally, resulting in wider dispersal of sediments and a lower angle of slope for the foreset beds. Furthermore, the saline waters tend to cause flocculation of the clays which will result in poorer sorting for the fine-grained sediments.

MODERN COMPARISONS

Widely studied and cited as a model for deltaic sedimentation, the Mississippi Delta is probably the best known modern deltaic environment. It is interesting to compare the New River Delta with the Mississippi complex to see what similarities and differences exist between these two deltaic environments. A comparison of factors which influence or describe the two deltas is presented on Table 2. Data for the Mississippi Delta are from Morgan (1970). If comparison is made between the New River Delta and a single pass and associated distributary system of the Mississippi complex, it is evident that the sedimentological characteristics as well as structural configuration, surface sediment distribution and surface morphology are strikingly similar. A major structural difference is in the thickness of prodelta and distal delta front sediments. The Mississippi is comprised of a very thick section of these sediments whereas they are extremely thin in the New River Delta. The three-dimensional geometry of the New River Delta closely resembles that of a Mississippi shoal water delta (Fisk, 1961). Sand distribution is strikingly similar. Sands in both deltas occur as fingers or veins, lensoid in section view, weaving complex patterns over the delta surface.

Shepard (1964) proposed several features that are characteristic of modern deltas. Lamination of fine sand and silt alternating with clays, a coarse fraction with abundant wood fibers and scarce foraminifera, and unusually high amounts of mica in the sediment are characteristics cited by Shepard and are manifest in the New River Delta as well as the Mississippi.

Shepard (1960) on the basis of his studies on the Mississippi also presented criteria for recognition of ancient deltas. These are (1) abundance of land plant remains, (2) unusually high mica content, (3) scarcity of invertebrates, (4) well-developed lamination in top set facies, (5) laminated sands over mudstones, (6) elongate sand bodies, and (7) bottom set beds high in organic remains. All of these are also present in the New River Delta.

It is evident that one can thus apply a "rule of similarity" to deltas formed under similar balances between sediment input and energy level. They will be similar in the facies formed and in the relations between these facies in a three-dimensional sedimentary body. Thus, one can identify the environment in the rock record even though the scales of different deltas may be very different.

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Table 2. COMPARISON OF FACTORS WHICH INFLUENCE OR DESCRIBE THE MISSISSIPPI AND NEW RIVER DELTAS

Factors	Mississippi Delta	New River Delta
River regime	moderate to large discharge silt and clay sediment load	low discharge silt and clay sediment load
Coastal processes	low wave energy low tidal energy	low wave energy low tidal energy
Structural behavior	significant subsidence, also downwarping and compaction allow thick sediment accumulation	stable
Climatic factors	humid temperate to subtropical	arid
Configuration	overlapping lobate birdsfoot distributary plains	single lobate distributary plain, corresponds to shoal water delta (Fisk, 1961)
Sediment distribution	very thick platform of prodelta clays and distal delta front silts and sheet sands on which are deposited bar finger type sands which grade laterally into interdistributary marsh, swamp, and lake sediments	thin prodelta and delta front sequence with bar finger sands on main distributary lobe which interfinger with interdistributary and marsh deposits. Mudflats fill quiet inlets.

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