2 The Imperial Sea: Marine Geology and Paleontology

The old sea bed, where once rolled the headwaters of the Vermilion Sea, is still a ghostly memory of its former state. And a memory not too dim, either. At dawn all the hollows of the badlands swim with misty haze that startlingly suggest water. And when sunset flings the long blue shadow of Coyote peak far out across the dry reaches the effect is breath-taking. There they are again, all those ancient bays and winding gulfs and lagoons. And beyond them the purple grey of the great sea.

Marshal South
***Desert Magazine* February 1940**

Thomas A. Deméré

The Imperial Sea: Marine Geology and Paleontology

Bahia de Los Angeles – a View of Former Anza-Borrego. (Photograph by Paul Remeika)

On a recent warm spring day as I was hiking up the soft slopes of a mud hill in the badlands near the Coyote Mountains of Imperial County, I came across fossilized shells of ancient organisms. The shells were weathering out of the otherwise uniformly fine-grained claystones that underlie this portion of the Colorado Desert. Upon close inspection, I found that the shells belonged to an extinct species of marine snail first recognized from this area by G. Dallas Hanna in 1926 and named *Turritella imperialis.* Surprisingly, Hanna's fossil Turritella is closely related to another species of *Turritella* known from fossil deposits on the Caribbean coast of the Panamanian Isthmus. As it turns out, many fossil shells from the Imperial Valley share close relationships with both fossil and living Caribbean species. When viewed in a broader geologic context, these related fossils suggest an historical connection for the two regions, but we are getting ahead of ourselves.

As I examined the shells at my feet, I paused to survey the geologic setting of this place. I was standing on a distinct stratum of light brownish-yellow fossiliferous siltstone tilted rather steeply to the northeast. The deformed stratum was overlain and underlain by uniformly massive beds of similar colored claystone, the whole exposed stratigraphic sequence probably several hundred meters in thickness. To the east across the breadth of the Carrizo Badlands were identical mud hills exposing similar tilted sequences of ancient marine siltstones and claystones, while to the west I could see a more resistant sequence of light gray and pale brown sandstone strata lying well below the claystones and resting on the twisted and altered metamorphic rocks of the main mass of the Coyote Mountains. The claystones, siltstones, and sandstones form an easily recognized sequence of sedimentary rocks that geologists have named the Imperial Group after the tectonically active valley where they occur.

Today there is no surface water in this part of the Imperial Valley except for the small oasis at the old Carrizo stagecoach station along Carrizo

Creek. Yet this parched earth contains locally abundant fossil remains of marine organisms. The juxtaposition of these two conflicting realities – shells of marine animals and parched earth – begs for explanation. Thanks to earth scientists like Hanna and many others, the conflicting realities are easily seen as historical snapshots in a dynamic evolving system driven by plate tectonics and playing for all eternity. Of course both realities exist, however, the reality of the fossil shells is one based in a world 4 to 7 million years past, while parched earth is the current reality. What the future reality will be, we can only predict.

Figure 2.1
Deguynos Formation.
Marine strata of the Deguynos Formation are well exposed in the eroded Carrizo Badlands (note people for scale). (Photograph by Tom Deméré)

As a paleontologist, I have learned how to live vicariously in ancient realities using the abundant clues preserved in the crustal rocks of the Earth. It is always rewarding when I can take people unfamiliar with reading these clues on a journey back in time, if only in their imaginations. To begin a trip like this it is useful to look at an area from two very different perspectives or scales. On the one hand, you have to get down and literally touch the Earth, while at the same time you need to step back and take more of a bird's-eye-view, remembering that there are times when you "can't see the forest for the trees."

Figure 2.2
Turritella imperalis.
Fossil shells of this extinct snail, weather out of a mudstone stratum in the Deguynos Formation, Carrizo Badlands. (Photograph by Tom Deméré)

To touch the Earth I mean to look closely at the rocks at your feet. For the paleontologist this generally means looking at clastic sedimentary rocks; those sedimentary rocks formed by the accumulation of sedimentary particles (mud, silt, sand, and/or gravel) under the influence of running water, blowing wind, or grinding glaciers. Such rocks, much like sandpaper, have textures largely determined by grain size. Thus, we can recognize coarse-grained, medium-grained, or fine-grained sandstones. Sedimentary rocks formed of silt-sized particles are called siltstones and those composed of clay-sized particles are called claystones or, if finely layered, shales. A rock unit made up of gravel is called a conglomerate, with modifiers added to reflect more specific particle sizes like pebble conglomerate, cobble conglomerate, or boulder conglomerate. These textural distinctions become important when we try to interpret the conditions under which a particular sedimentary rock stratum was deposited. Generally speaking, the larger the grain or particle sizes the stronger (swifter) the current responsible for transporting and depositing those particles. For example, a storm-swollen stream can transport pebbles and cobbles (not to mention cows and houses), while a slow-moving creek may only transport silt. Of course, interpreting the details of ancient depositional environments requires a lot more information, but these simple textural clues can provide a glimpse of

Figure 2.3
Plate Tectonic Setting of the Gulf of California.
Shown are the spreading centers, subduction zones, and transform faults.

the general conditions under which a particular rock stratum was formed. Fossil remains provide additional clues and at their coarsest level can indicate whether a stratum was deposited on land or on an ancient sea floor. Armed with these geological tools I have more than once been able to stand on an outcropping of fossil-rich marine sandstone and experience, in a virtual sense, tropical waters with their warm breezes and long vanished animal communities.

It is easy to get caught up in the minute details of sedimentary rocks and miss the bigger picture. This is especially true in the Colorado Desert where there are so many spectacular exposures of tilted, folded, and faulted strata. Stepping back and utilizing the broader perspective provided by maps and, these days, satellite images from space, we can see these sedimentary outcrops in their broader geologic context. The Colorado Desert is really a unique place, geologically. Like the East African Rift Valley of Kenya and Tanzania, the Colorado Desert lies in an area of active crustal thinning and continental rifting (see Dorsey, this volume, *Stratigraphy, Tectonics and Basin Evolution in the Anza-Borrego Desert Regions*). The southern portion of the Colorado Desert at the head of the Gulf of California is underlain at depth by a segment of the East Pacific Rise, a major crustal plate boundary that separates the largely oceanic Pacific Plate on the west from the largely continental American Plate on the east. Molten rock is welling up from deep inside the Earth along the axis of the East Pacific Rise, forcing the plates to spread away from each other. In places the central rift valley, where this spreading is concentrated, is broken and offset by transform faults with horizontal rather than vertical displacements. For most of its 8700 km (5437 mile) length the East Pacific Rise is a submerged volcanic mountain range on the ocean floor. This submerged mountain range enters the Gulf of California near Cabo San Lucas and extends along the length of the Gulf where it is broken into numerous short segments by transform faults. The combination of spreading and transform faulting is responsible for both the origin of the Gulf of California and the more than 250 km (156 mile) northward movement and clockwise rotation of Peninsular California (the landmass consisting of southern California and the Baja California Peninsula). At the head of the Gulf a major transform fault breaks through a short spreading segment of the East Pacific Rise and extends for over 1287 km (804 mile) northwestward to another spreading segment off the northern California coast at Cape Mendocino. This major transform fault is more popularly known as the San Andreas Fault and represents one of the few examples on Earth where transform faults deform continental rather than oceanic crustal rocks.

With these large-scale features of sea floor spreading and transform faulting in mind, it is easy to see why the Colorado Desert region of southern California is an area of high earthquake activity (transform faulting), as well as high geothermal activity (magmatic heat from sea floor spreading). These current conditions are nothing new for our region, which has been undergoing deformation since at least the middle Miocene, approximately 13 million years ago, when a proto-Gulf of California began to form in generally the same location as the modern Gulf. This proto-Gulf was flooded by ocean waters of the tropical eastern Pacific that entered the mouth of the proto-Gulf well to the south at about the latitude of present day Puerto Vallarta (20º N). As this narrow inland seaway filled, the shoreline transgressed northward, eventually reaching as far as San Gorgonio Pass in present day Riverside County. It was at this time, about 7 million years ago, that the oldest sandstone strata of the Imperial Group were being deposited in the shallow waters at the head of the proto-Gulf. The waters at the head of the proto-Gulf were warm and clear and supported diverse communities of marine organisms that lived in a variety of nearshore and intertidal paleoenvironments. Beginning about 5 million years ago, conditions changed dramatically when the ancestral Colorado River started depositing huge volumes of sediment into the northern end of the proto-Gulf. This tremendous influx of sediment was generated as the mighty river eroded headward into the Colorado Plateau of Arizona, excavating deep canyons including the Grand Canyon. The resulting sediment load caused increased turbidity of gulf waters and the eventual deposition of thousands of meters of clay and silt. Over time, the rapidly expanding river delta formed a massive “sediment dam” that forced the shoreline of the Gulf southward to near its present position, leaving the northern end of the proto-Gulf “high-and-dry.” Actually, not that high and dry since the low-lying region north of the delta became first a series of Pliocene and Pleistocene fresh water and ephemeral playa lakes, followed by braided streams, and eventually coalesced alluvial fans. These later non-marine paleoenvironments and their fossil organisms are the subject of other chapters in this book.

Having presented this rather abbreviated overview of the late Cenozoic history of the Imperial Valley, we can now focus more closely on the ancient marine strata of the Imperial Group and its preserved biological record of fossils.

Latrania Formation

Geologists have named the older pre-delta marine sandstones at the base of the Imperial Group the Latrania Formation. In the Coyote Mountains, Fish Creek Mountains, and Vallecito Mountains the Latrania Formation (Figure 2.4) can be up to 100 meters (330 ft) thick and typically consists of a sequence of coarse-grained strata that include gray to red-brown, medium-grained, massive, micaceous sandstones; gray, fine-grained, laminated, and cross-stratified, micaceous sandstones; red-brown bioclastic sandstones; and pale yellow skeletal (shelly) limestones. In several areas, the basal marine sandstones of the Latrania Formation interfinger with coarse-grained alluvial fan conglomerates. These fanglomerates, as they are called, suggest that erosion and sedimentation rates were relatively high during the initial filling of the proto-Gulf in the late Miocene. A good place to see these basal deposits is at the mouth of Fossil Canyon on the south slopes of the Coyote Mountains near Ocotillo. As you walk up the canyon the sedimentary strata exposed in the canyon walls gradually change from coarse-grained fanglomerates with sharply angular cobbles and boulders to fine-grained marine sandstones. About 1000 meters (3300 ft) up the canyon from the Bureau of Land Management fence, a resistant one meter (3.3 ft) thick shelly limestone bed crosses the canyon floor as a distinctive, tilted stratum. A close inspection reveals that this limestone is packed with irregular rounded pieces of colonial corals, broken shells of oysters and scallops, and sandstone molds of marine snails. This limestone stratum, like most of the Imperial strata exposed in Fossil Canyon is tilted rather steeply to the east, the result of tectonic forces associated with the nearby Elsinore Fault. Overlying the limestone is a rather thick sequence of coarse-grained sandstones that contain local concentrations of fossil scallops, oysters, cones, conchs, whelks, sand dollars, and sea biscuits. For the most part, these fossils are not that well preserved and primarily consist of internal and external molds of marine clams and snails. The original calcium carbonate (in the form of the mineral aragonite) of the fossil shells has been leached away by slightly acidic groundwater percolating through the buried sandstone strata. As the shell material dissolves, some of the calcium carbonate is precipitated in the pore spaces between individual sand grains. When uplift and erosion eventually expose the fossil-bearing strata, they begin to crumble "releasing" the buried fossils, which now consist of hardened sandstone impressions of the internal or external surfaces of the shells. Typically, the internal molds are the most useful to paleontologists because, although the shell material is now lost, the mold preserves much of the form of the original shell allowing for taxonomic identification.

Figure 2.4
Latrania Formation.
Wind eroded sandstones of the Latrania Formation are exposed in the Coyote Mountains. (Photograph by Tom Deméré)

Not all of the fossils from the Latrania Formation are preserved as internal and external molds. For species that construct their shells with the mineral calcite, another form of calcium carbonate, the acidic groundwaters do not destroy the original shell material. Fossils of these species, which include scallops, oysters, certain snails, corals, and sand dollars, are preserved as original shell material and often retain a great deal of important surface morphology. Some even preserve remnant shell coloration (see Deméré and Rugh, this volume, *Invertebrates of the Imperial Sea*).

Figure 2.5
Sandstone Molds.
Internal molds of marine mollusks, note large cone snail left center, weather out of the Latrania Formation in the Coyote Mountains. (Photograph by Tom Deméré)

The basal marine sandstones of the Latrania Formation are not always associated with alluvial fan deposits and elsewhere in the Imperial Valley lie directly on older volcanic and/or metamorphic rocks that form the core of the Coyote and Fish Creek mountains. The contact between the Latrania Formation and these crystalline rocks is very irregular and represents an ancient eroded land surface that was rapidly submerged as marine waters spread northward with the advancing Miocene shoreline of the Imperial Sea. In some places, low cliff faces and benches carved during the Miocene into the volcanic and metamorphic crystalline rocks serve to mark the location of former shorelines and sea cliffs. Careful geologic studies of these ancient shorelines suggest that the Imperial coastline was quite irregular and consisted of a mixture of prominent headlands, steep and linear sea cliffs, eroded embayments, and rocky islands. Such a description could also be made for long stretches of the modern Gulf coast of Baja California. Good exposures of the Miocene shoreline features occur on the south slopes of the Coyote Mountains between Fossil Canyon and Painted Gorge.

The rarity of clay and silt in the Latrania Formation suggests that deposition generally occurred in relatively clear marine waters at intertidal to subtidal depths. This hypothesis is supported by the occurrence of locally diverse and abundant assemblages of fossil marine invertebrates dominated by mollusks, echinoderms, and importantly, colonial corals. As already mentioned, many of the fossil invertebrate organisms found in the Latrania Formation are closely related to species found in the Caribbean region, either as fossils or as still living organisms. Their occurrence in the Latrania Formation suggests some degree of faunal interchange between the two regions. Compelling geologic evidence from Central America further indicates that a direct marine connection formerly existed between the Caribbean and the tropical eastern Pacific via seaways across southern Costa Rica, central Panama, and western Colombia. Today this area is occupied by the Isthmus of Panama, which was uplifted above sea level during the Pliocene Epoch approximately 3.5 to 3.1 million years ago. Prior to that time the Central American Seaway formed the southern shoreline of the North American continent and separated North America from the island continent of South America. Given this very different paleogeography, it is possible to visualize a former unbroken tropical region encompassing the Caribbean Sea, western Gulf of Mexico, and equatorial eastern Pacific that supported a shared community of marine organisms. Paleontologists refer to this region as the Tertiary Caribbean province. Surface ocean currents of the eastern Pacific (Equatorial Countercurrent) and Caribbean (Caribbean Current) presumably flowed west to east and east to west, respectively, through the Central American Seaway and provided a means for dispersing larvae of various marine invertebrate phyla. Countercurrents flowing north along the west coast of Mexico, in turn, allowed dispersal of Tertiary Caribbean species into the proto-Gulf of California. This was especially the case for species of colonial corals. Paleontologists have recognized at least nine different species of colonial corals from the Latrania Formation (Vaughan, 1917), only one of which belongs to a genus that still lives in the eastern Pacific. All of the other fossil species belong to genera that evolved in the Caribbean and only survive there today.

Figure 2.6
Carcharodon sp.
Fossil tooth of this large shark (SDSNH 86003) was collected from the Latrania Formation in the Coyote Mountains. (Photograph by Barbara Marrs)

Besides preserving a record of tropical Tertiary Caribbean affinities, the Latrania Formation also preserves interesting records of ancient marine ecological and environmental conditions. Paleontologist Rodney Watkins (1990a, 1990b) has discovered rare rocky intertidal deposits of skeletal (shelly) limestone in the Latrania Formation as exposed in the Coyote Mountains. These rather unique deposits lie directly on marble of the ancient metamorphic bedrock complex and preserve a rocky shore trace fossil community consisting of burrows and borings of rock-boring bivalves, sponges, worms, and echinoids, as well as body fossils of encrusting barnacles and corals (see Appendix, Table 2). Outcrops of intensely bivalve-bored marble in this area occur in association with wave-eroded sea cliffs and serve to define former shorelines around prehistoric rocky islands of the Miocene Imperial Sea. In this same area, local concentrations of fossil corals occurring directly on wave eroded bedrock platforms appear to represent ancient coral patch reefs that formed in shallow nearshore waters. Walking along this ancient shoreline, it is almost possible to hear the Miocene waves breaking against the low sea cliffs and to imagine the currents swirling around the margins of slightly submerged coral reefs.

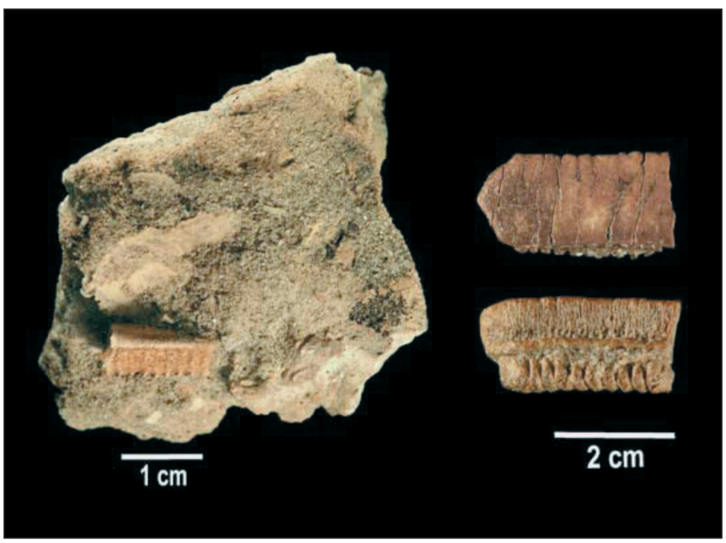


Figure 2.7
Myliobatis sp.
Tooth plates of the bat ray *Myliobatis* sp. (SDSNH 86005) were collected from the Latrania Formation in the Coyote Mountains. (Photographs by Barbara Marrs)

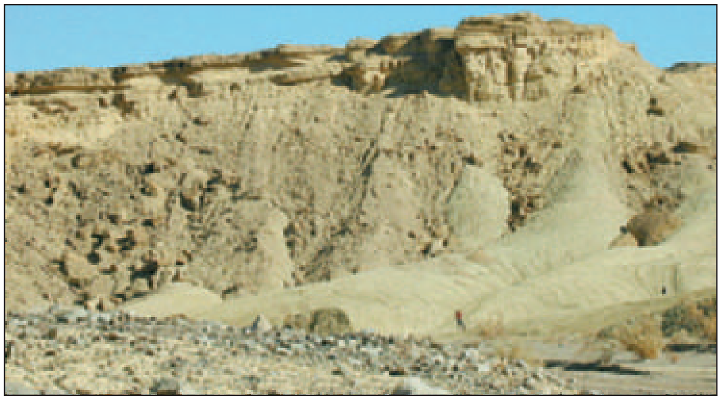
Susan Kidwell is another scientist who has studied the fossiliferous marine deposits of the Imperial Valley. Her studies (Kidwell, 1988; Winker and Kidwell, 1996) have focused on major fossil shell beds in the Latrania Formation. Some of these shell beds are as much as 7 meters (23 ft) thick and contain a complex variety of fossil concentrations including sandy and muddy layers with low diversity assemblages of oysters and snails, gritty limestone layers with low diversity oyster and coral assemblages, and limey sandstone layers with very diverse clam, snail, and echinoid assemblages. Typically, the fossils occur as jumbled concentrations of whole and partial shells suggesting that the shell beds represent long-term accumulations of dead skeletal debris on subtidal sea floors, probably below the level reached by normal wave action.

Although the bulk of fossils known from the Latrania Formation represent species of invertebrate organisms like corals, molluscs, crustaceans, and echinoderms, recent field work by staff of the San Diego Natural History Museum has resulted in the recovery of partial remains of marine vertebrates including teeth of sharks, rays, and bony fishes, as well as bones of sea turtle and marine mammals (Deméré, 1993). The fossil shark and ray assemblage currently consists of the bat ray *Myliobatis* sp. (Figure 2.7), the extinct giant shark *Carcharocles megalodon*, the white shark *Carcharodon* sp. (Figure 2.6), and the sand shark *Odontaspis* sp. Fossil bony fish from the Latrania Formation include a giant barracuda *Sphyraena* sp., a sheeps head *Semicossyphus* sp., and a triggerfish family Balistidae. A single carapace plate of a sea turtle belonging to the family Cheloniidae has been recovered from sandstones of the Latrania Formation. Fossil remains of marine mammals from this rock unit include a partial rib of a sea cow and several partial lower jaws and ribs of a baleen-type whale. All of these vertebrate fossils occur in the shell-rich strata of the Latrania Formation and probably represent scattered remains that were transported and deposited by localized currents. Unfortunately, complete or even partial skeletons of marine vertebrates have so far eluded the dogged attempts by field parties of vertebrate paleontologists to find them. Rather than being seen as a "half empty glass," this meager vertebrate fossil assemblage suggests that there is still a great deal of paleontological work to be done in these marine rocks and that many more fossils are to be found.

Figure 2.8
Baleen Whale.
This fragmentary rib of a baleen whale (SDSNH 46015) was collected from the Latrania Formation in the Coyote Mountains. (Photograph by Barbara Marrs)

Deguynos Formation

Figure 2.9
Deguynos Formation.
Cross-bedded deltaic sandstones and pro-delta mudstones of the Deguynos Formation are well exposed in Painted Canyon, Coyote Mountains (note person in foreground for scale). (Photograph by Tom Deméré)



As mentioned earlier, beginning about 5 million years ago the ancestral Colorado River began building its massive delta at the head of the proto-Gulf of California. This Pliocene event is recorded in the sedimentary rocks of the Imperial Group by a dramatic change from the coarse-grained sandstones of the Latrania Formation in the lower portion of the Imperial Group to the fine claystones of the Deguynos Formation in the upper portion of this rock unit. The Deguynos Formation is at least 1000 meters (3300 ft) thick in the Carrizo Badlands and consists primarily of greenish-gray to grayish-olive massive claystones, yellowish-gray laminated siltstones, light gray silty very fine-grained sandstones, and gray shell coquinas. Resistant skeletal

Figure 2.10
Coquina.
This massive bed of oyster shells is in the Deguynos Formation in Painted Canyon, Coyote Mountains. (Photograph by Tom Deméré)

limestone and bioclastic sandstone strata typically weather to a dark brown color, while the softer claystone and siltstone strata weather to a pale yellow color and often develop a blistered expansion surface littered with white, platy crystals of Gypsum, calcium sulfate. Because of relatively high rates of sediment accumulation in and around the massive delta of the ancestral Colorado River, fossils are generally rare in the Deguynos Formation. Highly fossiliferous strata, however, do occur in the middle and upper portions of the formation, which is characterized by resistant oyster-shell coquina strata varying in thickness from less than one meter (3.3 ft) to over four meters (13 ft). The coquinas are often cross-bedded and contain tightly packed concentrations of whole and fragmentary shells in a very hard calcite cemented sandstone matrix. Fossil assemblages in these coquinas are typically dominated by shells of the small oyster, *Dendrostrea vespertina.* Some coquinas also contain common shells of the bivalve, *Anomia subcostata*, and rarer shells of the small scallop, *Argopecten deserti,* and the snail, *Turritella imperialis.* Rodney Watkins has closely studied these coquinas in the Coyote Mountains and Fish Creek Mountains and concluded that they formed in large submerged distributary channels on the shallow marine portions of the ancestral Colorado River delta (Watkins, 1992). The dense concentrations of oyster shells in these coquinas are the result of swift currents transporting the large shells as bedload (suspended in the water mass) particles while flushing the finer-grained sand and silt offshore into deeper water. Fossil assemblages in the mudstone strata underlying many of the coquinas include widely dispersed fossils of the pholads (rock piddock clam), *Cyrtopleura costata,* and the pen shell, *Pinna latrania,* often in life position. By life position, I mean that the fossil shells are upright in their original burrows rather than lying on their sides in a transported death pose. These occurrences suggest that the infaunal (living in mud or sand bottom) pholads and pen shells were buried alive by deltaic sediments and not ripped up by storm currents and transported to a common site of deposition. There is a difference between fossil concentrations that represent life assemblages versus those that represent death assemblages. With the former paleontologists are provided a glimpse of ancient organisms as they lived with their associated community members and actual

Figure 2.11
Valenictus imperialensis.
Left humerus (upper arm bone) of the extinct Imperial walrus (side and rear views of a cast of LACM 3926). (Photograph by Barbara Marrs)

population densities. The latter preserves more of a jumble of organisms from a wider range of communities and habitats that were only brought together in death.

Figure 2.12
Valenictus imperialensis.
Fragmentary femur (upper leg bone) of the extinct Imperial walrus collected from the Deguynos Formation, East Mesa (ABDSP 2441/V6747.01). (Photograph by Barbara Marrs)

Some of the shell beds in the Deguynos Formation have produced rare remains of marine vertebrates including teeth of sharks and rays, as well as bones of marine mammals. Unfortunately, as was the case in the Latrania Formation, these vertebrate remains are fragmentary and do not include even partial skeletons. The fossils however, do give us a hint of the types of animals that did live in the turbid waters of the Pliocene Imperial Sea (see note below). Fossil bones of an extinct species of walrus, *Valenictus imperialensis*, recovered in the Painted Gorge and Fish Creek areas of the Carrizo and Vallecito Creek-Fish Creek Badlands are the only records of walrus from the proto-Gulf (Figures 2.11, 2.12, 2.13). Nearly complete skeletons of another species of *Valenictus* (*V. chulavistensis*) have been recovered from Pliocene-age sandstones near San Diego and preserve close anatomical similarities with the modern Arctic walrus, *Odobenus rosmarus.* Similarities include large tusks in the upper jaw, an arched and elongate palate, heavy muscle attachments at the back of the skull, and fused bony "chin." The recovery of these temperate to subtropical walruses in Pliocene rocks of San Diego and the Imperial Valley supports the hypothesis that the ice-loving aspect of modern *Odobenus rosmarus* is the result of fairly recent evolutionary events of the Pleistocene.

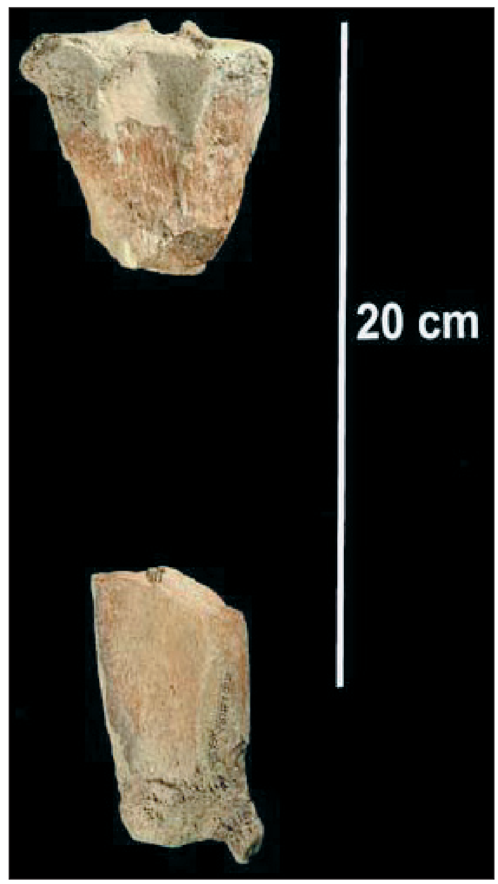


Figure 2.13
Valenictus imperialensis.
Left tibia (lower leg bone) of the extinct Imperial walrus (ABDSP 2441/V6747.02) collected from the Deguynos Formation, East Mesa. (Photograph by Barbara Marrs)

Isolated fossil vertebrae of small dolphins have recently been recovered from the Fish Creek exposures of the Deguynos Formation and represent the first record of Pliocene odontocete (toothed whale) cetaceans from the Proto-Gulf (Figures 2.14, 2.15). These new discoveries underscore the fact that there is still much to learn about the marine vertebrate fauna of the Imperial Sea.

The marine sedimentary rocks of the Deguynos Formation are overlain by and interfinger with mid-Pliocene age (3.5 to 4.0 Ma) playa lake and river deposits of the Palm Spring Group. The transition between these two geological units records the final period of silting of the head of the Imperial Sea and of regression of the proto-Gulf shoreline to near its modern position south of the international boundary. The present-day Laguna Salada in northeastern Baja California south of Mexicali serves as a useful model of the depositional setting of the final sediments of the Imperial Group and the initial sediments of the Palm Spring Group (see Dorsey, this volume).

Today the Imperial Sea is only a memory, a memory preserved in the Miocene and Pliocene sedimentary rocks of the

Anza-Borrego Desert State Park and adjoining federal and private lands. The opportunity to tap into this memory through a firsthand encounter with the exposed geological and paleontological record is worth the trip. The experience can be life altering if you come away with some sense of the vastness of geological time and with the realization that the current world is just a snapshot of a dynamic and evolving sequence of past and future worlds.

Figure 2.14
Dolphin Vertebra.
Side view of a weathered lumbar (lower back) vertebra from a fossil dolphin (ABDSP 2442/V6746) collected from the Deguynos Formation, East Mesa. (Photograph by Barbara Marrs)

Figure 2.15
Dolphin Vertebra.
Front and side views of a caudal (tail) vertebra from a fossil dolphin (ABDSP 2441/V6745) collected from the Deguynos Formation, East Mesa. (Photograph by Barbara Marrs)

The Ethics of Fossil Collecting

The fossil-bearing deposits of our local desert generally occur on public lands, either under U.S. Bureau of Land Management or California State Parks control. Collection of fossils on these lands is strictly regulated and research permits are required.

In this age of explosive human populations, we need to realize that the pioneer mentality of our forebears has to be tempered by thoughts of the needs of future generations. We can no longer lay claim to all we see and in the case of fossils, we should be content to observe their occurrence without requiring a souvenir.

I have seen areas where fossils were formerly abundant almost completely stripped of them by curious visitors. Unfortunately, in most cases the collected fossils were probably quickly forgotten or later thrown out when the collector grew tired of the clutter. Even museums need to be content in some cases to "only take pictures" and leave an area intact for future visitors. Please keep these thoughts in mind during your next visit to the desert and enjoy the geologic experience.