DISSECTED GRAVELS OF THE RÍO COPIAPÓ VALLEY AND ADJACENT COASTAL AREA, CHILE

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Abstract.—Cenozoic history of the area is largely shown by the sediments and landforms of upland-gravel, stream-terrace, and marine-terrace deposits. Upland gravel was probably deposited in late Tertiary time before the present course of the Río Copiapó was established. Fluviatile-terrace gravel represents a major episode of river aggradation during an interruption of a long Pleistocene cycle of valley deepening. Surfaces of marine-terrace deposits at altitudes of 95 to 140 m and 175–235 m above sea level may represent interglacial or interstadial episodes, or both. Local faulting has vertically displaced a high marine terrace at least 40 m.

Much of the Cenozoic history of the valley of the Río Copiapó, one of the few through-going rivers of extremely arid northern Chile, and of the adjacent coastal area, must be interpreted through study of dissected gravel deposits. These deposits are here described and related to the sequence of events that produced and modified the present river valley and coastal terrace.

DRAINAGE AND RELIEF

The Río Copiapó (fig. 1) is the major (and only perennial) stream in the area. The channel of the Río Copiapó falls a little more than 1,200 meters in a distance of 156 kilometers. The mean discharge of the stream near its mouth is about 200 liters per second, but along much of its upper and middle courses the flow is perhaps 3 to 5 times that much. The present discharge of the river bears no relation to its natural regimen because large quantities of water are withdrawn for irrigation. Tributaries of the Río Copiapó are all without perennial surface flow in the area of figure 1.

The terrain is generally rugged; steep slopes are common, particularly near the valleys of the river and of some of its tributaries. Some interfluves 1,500 to 2,500 m above sea level, or as much as 460 m higher than the river nearby, are parts of a less-rugged matureland. Fluviatile terraces which are a few meters to 100 m or more above the river extend along the sides of major valleys, and a broad marine terrace is present along the coast.

UPLAND GRAVEL

Upland gravel occurs as remnants of a broad rolling plain that formerly covered extensive areas on both sides of the Río Copiapó valley from about 16 km southeast of Elisa de Bordo to Pabellón (fig. 1). The plain is considered to be a southerly extension of the pampa of northern Chile, because it follows the same alinement as that feature and is at the same altitude, 1,000 to 1,300 m above sea level. The plain is interrupted by hills and ridges of resistant rock (Segerstrom, 1963b).

West of Elisa de Bordo an east-facing escarpment which attains a height of 460 m above the river (fig. 2, *left*) exposes a section of horizontally bedded gravel, 60 to 100 m thick, that overlies southeast-dipping conglomerate and volcanic rocks of the Cerrillos Formation (Cretaceous) with great angular discordance (fig. 3). The gravel deposit is a mixture of boulders, cobbles, and pebbles of volcanic, plutonic, and sedimentary rocks, in a matrix of sand, silt, and clay. The deposit is ill sorted, thick bedded, and, so far as is known, unfossiliferous. The proportion of granite cobbles is disproportionately high in relation to the limited occurrence of plutonic rock in the vicinity, which suggests that part of the gravel material was transported from distant outcrops in the high Cordillera. Therefore, the deposit and landform presumably were very extensive.

The upland gravel is important in the physiographic history of the region; like the deeply weathered bedrock that underlies it, the upland gravel is a relic

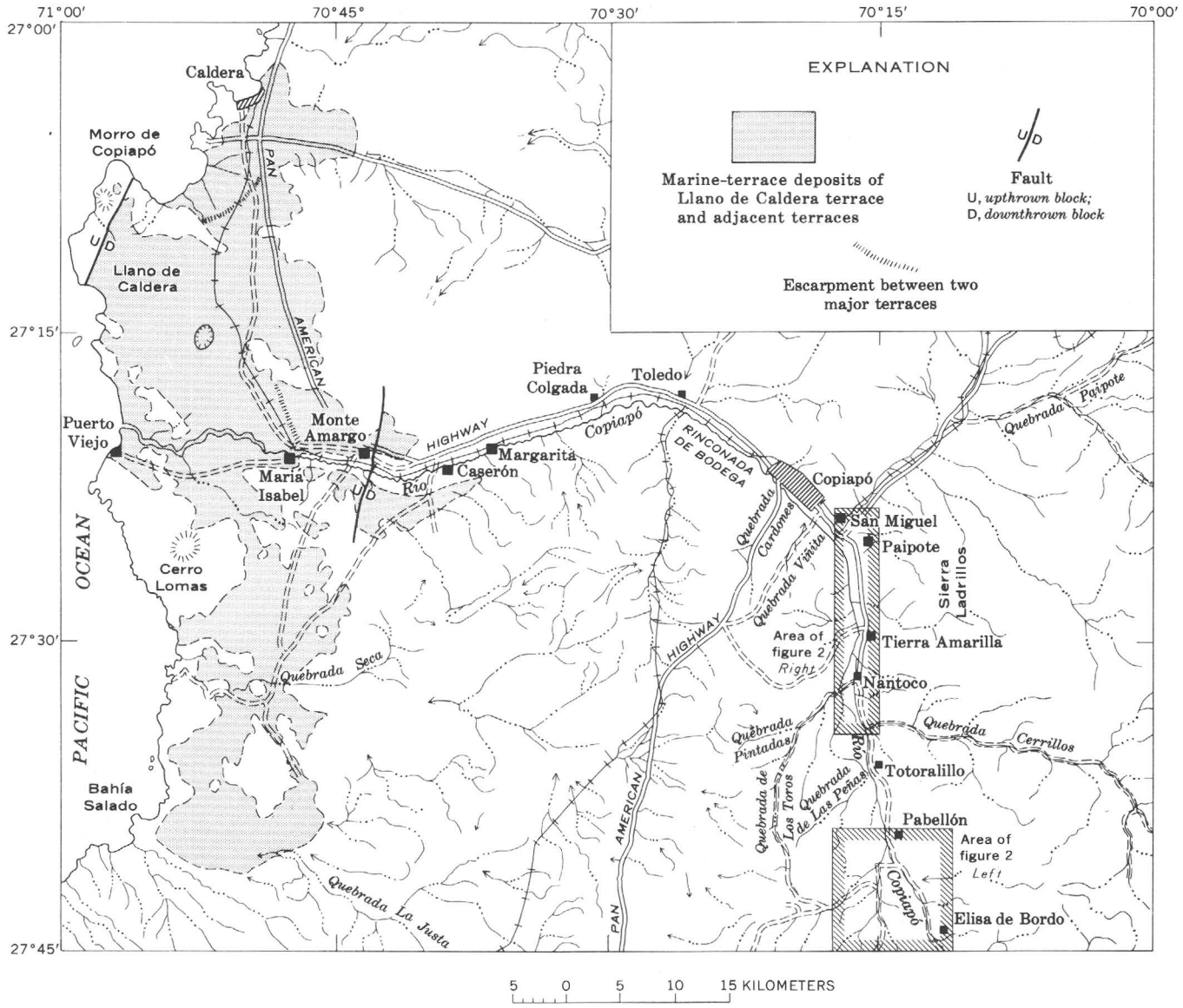
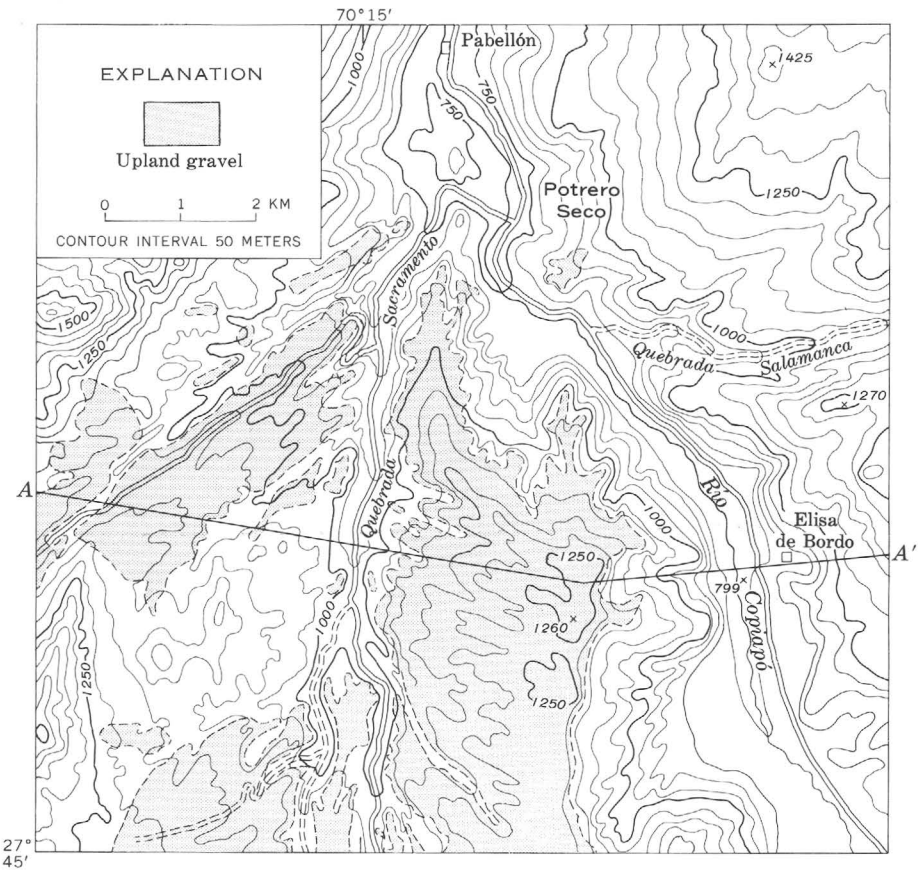


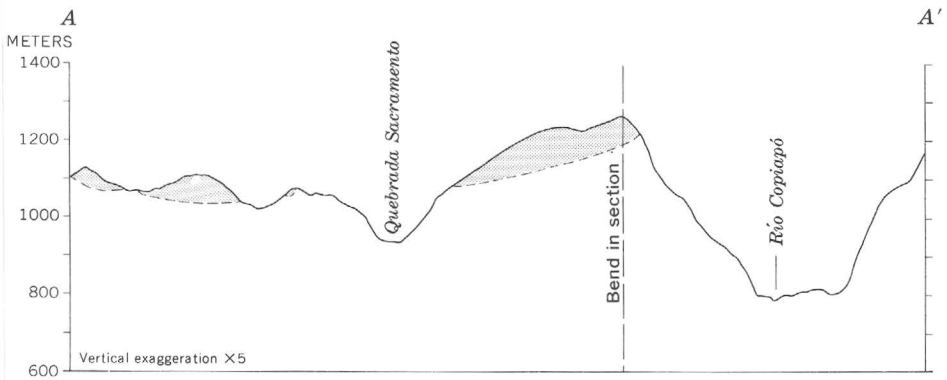
FIGURE 1.—Index map of part of the Río Copiapó watershed, and adjacent areas, showing locations of figure 2 *left* and *right*, and distribution of marine-terrace gravel. Base map from World Aeronautical Chart 1317, Point Morro.

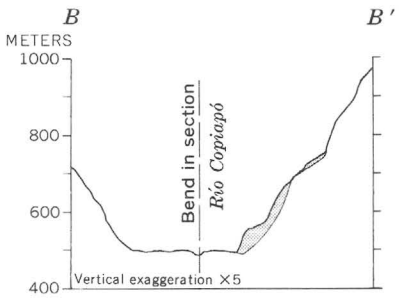
of a matureland that antedates the formation of the Río Copiapó valley and dates back to Tertiary time (Segerstrom, 1963b, p. 517). At least locally the river was superposed on the gravel cover at the east side of a broad ancestral valley that extended from the south along the present Quebrada Sacramento.

STREAM-TERRACE DEPOSITS

Stream-terrace deposits, or "fringing gravels," which are fill deposits along the Río Copiapó and its tributaries, are much younger than the upland or "mantling" gravels (Willis, 1929, p. 95). The most extensive fluviatile terrace along the Río Copiapó flanks the east side of the valley for about 16 km, from Nantoco to San Miguel (fig. 2, *right*). The terrace, which descends relatively steeply from Sierra Ladrillos toward the Río Copiapó, consists chiefly of material derived from the east rather than from farther up the main valley (to the south). The deposit has been deeply dissected, and the underlying bedrock is exposed in large areas between the terrace segments. The segments typically stand about 70 m above the adjacent valley floor at the lower brink of the terrace and 150 m at the upper limit. However, at some places where the terrace escarpment has been cut back unusually far from the river, the brink is as much as 100 m or more above







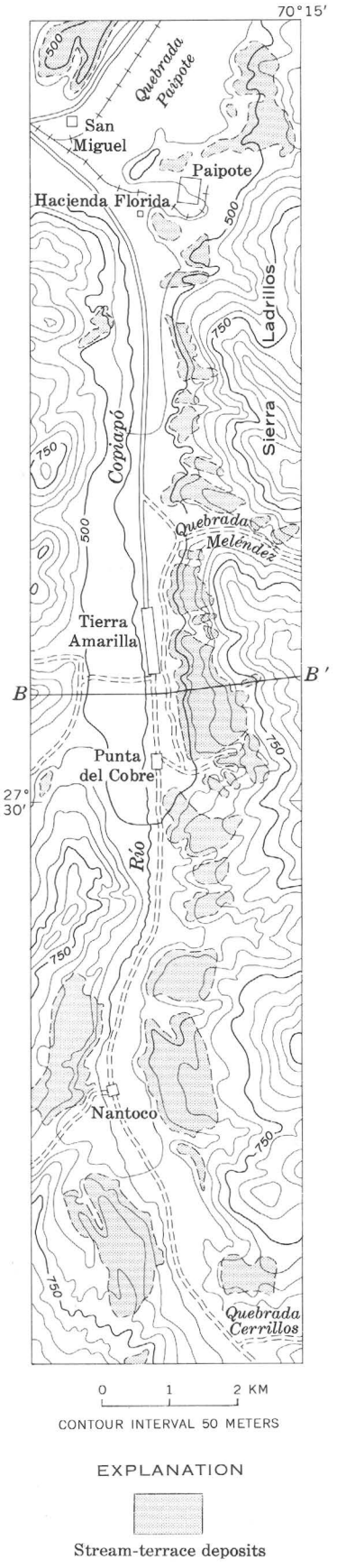


FIGURE 2.—Maps and sections showing distribution of upland gravel and stream-terrace deposits in two areas in the Río Copiapó valley. *Left*, upland gravel in the vicinity of Elisa de Bordo; *right*, Stream-terrace deposits in the vicinity of Punta del Cobre. Locations of areas shown on figure 1. Base maps from Cerrillos, Copiapó, and Pintadas quadrangles, Instituto Geográfico Militar, Santiago.

the valley floor, and the apices of some coalescing fans that are major components of the terrace deposit stand 225 to 250 m above the valley.

Two well-preserved terrace remnants remain on the west side of the river near Nantoco (fig. 2, *right*). The more southerly remnant has an abrupt eastern escarpment 107 to 115 m high that drops directly to the river. On the opposite side of the river, the brink of a terrace north of the mouth of Quebrada Cerrillos is 93 m above the river.

Small remnants of fluviatile-gravel terraces with escarpments approximately 20 m high occur along the northern flank of the valley between San Miguel, at the mouth of Quebrada Paipote, where the Río Copiapó swings westward, and a point about halfway between Toledo and Piedra Colgada. Similar remnants on the southern flank extend up Quebrada Viñita, Quebrada Cardones, and along Rinconada de Bodega. An isolated terrace of about the same height occurs far downstream, to the north of Margarita. Locations are shown on figure 1, but because of space limitations the fluviatile terraces are not shown on this figure.

The character of the bedding and sorting in the stream-terrace deposits is highly variable. At some places, bedding is excellent; at most places it is ill defined. Some of the thickest deposits contain boulders as much as 2 m in diameter set in a matrix so clay rich as to be virtually impervious. In some lenses of gravel- to silt-size material, sorting is excellent. All gradations of sorting between the two extremes are exhibited. No plant remains or other fossils have been found in the stream-terrace deposits, despite intensive search.

Multiple terraces are present on the lower reaches of Quebrada de las Peñas, a tributary of the Río Copiapó west of Totoralillo (fig. 1). About 1 to 2 km upstream from the west edge of the Río Copiapó valley, five terraces in the fill deposits of the quebrada rise steplike above the channel (fig. 4). The highest of these terraces is about 20 m above the present watercourse, and the lowest one 4 to 5 m. Such a valley-in-valley cross profile, where more than one terrace is present on both sides of the stream channel, is fortuitous and highly localized. The present channel of the quebrada is being widened by the undercutting and caving of its gravel banks during the infrequent storms that produce runoff, and this is probably how most of the intermediate terraces have been destroyed. The most persistent terrace is the highest, at the 20-m level.

The terrace levels at 70 to 115 m along the main valley represent a major episode of river aggradation—an interruption of a long Pleistocene valley-deepening cycle. The 20-m level is evidence of a later degradational episode. The lower levels along the Quebrada de las Peñas represent minor degradational episodes in a Recent cycle of large-scale aggradation whose existence is shown by a thick fill of clastic deposits over bedrock in the main valley bottom. The bottom fill has been modified by later smaller scale trenching.

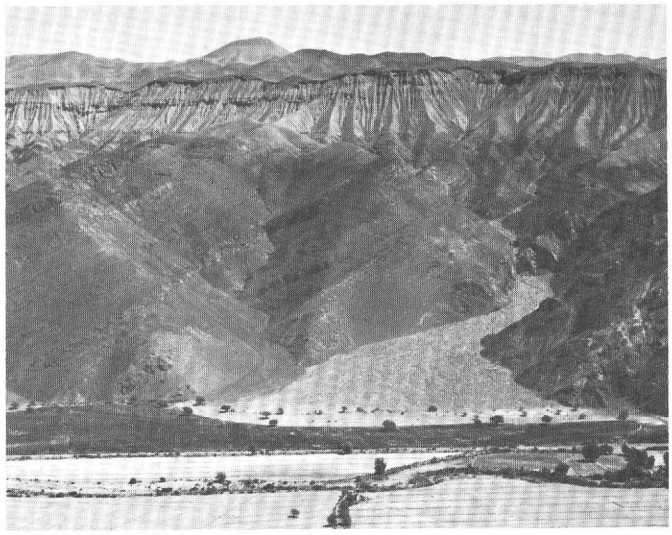


FIGURE 3.—View westward from Elisa de Bordo, showing horizontal deposits of upland gravel that unconformably overlie tilted beds of the Cerrillos Formation.

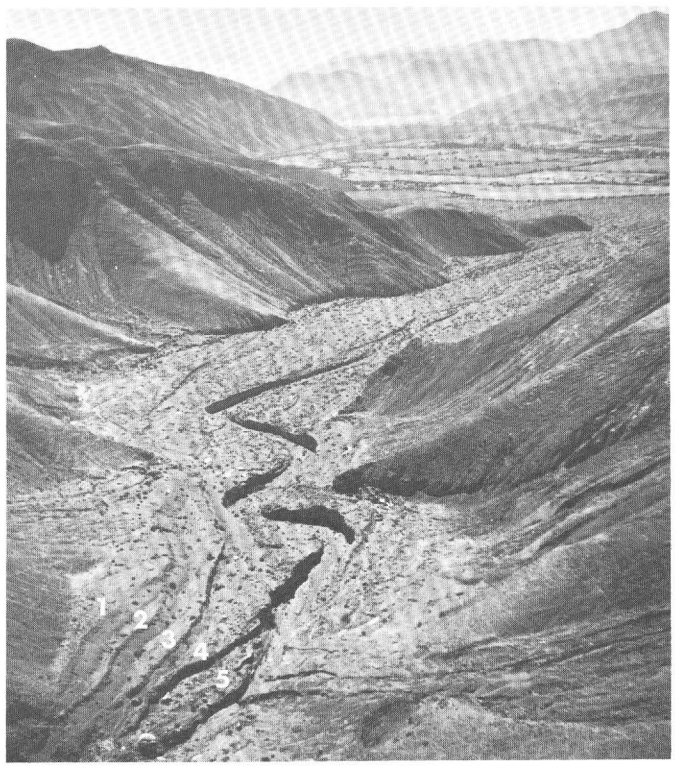


FIGURE 4.—View northeastward down Quebrada de las Peñas toward the Río Copiapó valley, showing five stream terraces in foreground (numbered consecutively from oldest to youngest).

MARINE-TERRACE DEPOSITS

From Margarita to the sea (fig. 1) the Río Copiapó valley traverses an area that was a marine embayment during Pleistocene time. Several marine terraces are preserved, the main one of which is called the Llano de Caldera terrace.

At the latitude of the Río Copiapó, the Llano de Caldera terrace extends about 16 km eastward, rising from about 95 m above sea level at the brink of a seaward escarpment to 137 m at the foot of the escarpment north of María Isabel. The terrace extends 60 km southward from near Caldera to Bahía Salado. It is 8 to 16 km wide. Eolian deflation in a central undrained zone has produced a basin whose bottom is 83 m above sea level (shown with depression contour on fig. 1).

Along the north side of the river valley a higher terrace extends about 8 km eastward, rising from about 175 m at the brink of the scarp north of María Isabel to 230 m at the brink of an east-facing escarpment. A north-northeast-striking fault which crosses the valley (fig. 1) has dropped the eastern block 40 to 50 m with respect to the western block. From the foot of the fault scarp the downfaulted terrace extends as much as 11 km farther up the valley, on the south side of the river, to an altitude of 180 m, where the terrace level becomes practically that of the present floor of the Río Copiapó valley.

On very narrow elevated beaches at the eastern edge of the former embayment, shells have been found as high as 268 m above sea level.

Along the present coast, an escarpment about 10 km south of Caldera (fig. 1) marks the boundary between the Llano de Caldera terrace and a lower zone of terrace levels 15 m to 60 m above sea level. Elsewhere, this zone is very narrow and because of scale limitations is not shown on figure 1.

Marine beds that underlie the Llano de Caldera and higher terrace surfaces to the east are sandy and gravelly; they contain abundant mollusks and some sharks' teeth, most of which are morphologically undistinguishable from the remains that litter modern beaches (Segerstrom, 1963a). Specimens of the mollusk *Isognomon* collected near Quebrada Seca at about 100 m above sea level are larger than the average of modern forms; they may represent a warm-water species (José Corválan, oral communication, June 1962). Hence, at least the uppermost Llano de Caldera terrace sediments were probably deposited during an interglacial or interstadial period.

There is abundant evidence of Quaternary crustal movements along the Chilean coast (Segerstrom, 1964, p. 167–168); in northern Chile the amount of general crustal uplift probably exceeds that of eustatic fall of sea level. The faults near Monte Amargo and the Morro de Copiapó are local evidence that at least part of this uplift is differential.

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