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## Abstract

In the Bucaramanga region, the Oriental Cordillera shows a very peculiar relief consisting of mesas separated by deep and abrupt canyons cut in sedimentary and crystalline rocks. These landscapes are underlined by the sub-arid climate which characterizes these steep valleys, often lacking vegetation cover. These contrasted life zones and geomorphological evolution experienced by the region make it an interesting place both for earth scientists and tourists. The recent installation of a cable car which crosses the canyon contributes to its attractiveness as a scenic place.

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## Keywords

River canyons • Mesetas • Semi-arid geomorphology

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## 6.1 Introduction

The Chicamocha River source is situated near Tunja, the capital of the Department of Boyacá. After a meandering tract in the highlands, which rise to 2500 m a.s.l, the valley becomes a canyon near Paz de Río. The river flows in the bottom of a gorge until it merges with the Suarez River in the Department of Santander to become the Sogamoso River, which finally discharges its waters in the Magdalena River (Fig. 6.1). The best expression of the canyon is found around the city of Bucaramanga; it can be appreciated from the roads from San Gil to Bucaramanga and from this city to Zapatoca. The canyon can also be seen from the air by taking the cable car which, since 2009, crosses the valley from the Chicamocha National Park, in the road from San San Gil to Bucaramanga, to the Santos Mesa. This park is located 54 km from Bucaramanga, a car ride of about 1 h.

Julivert (1958) described the canyon area as a Mesozoic block, which he called the “Mesetas region,” and interpreted it as an extensive tabular relief which stretches from Bucaramanga to the surroundings of Velez. It is characterized by the presence of horizontal strata cut by two important faults: the Santa Marta-Bucaramanga and the Suarez Faults. The latter, trending north to south, divides the meseta relief in two structural zones: the western one, where the town of Zapatoca is located and the eastern one, where lie the Mesa de los Santos (Gomez and Cuervo 2012) and Barichara (Fig. 6.2).

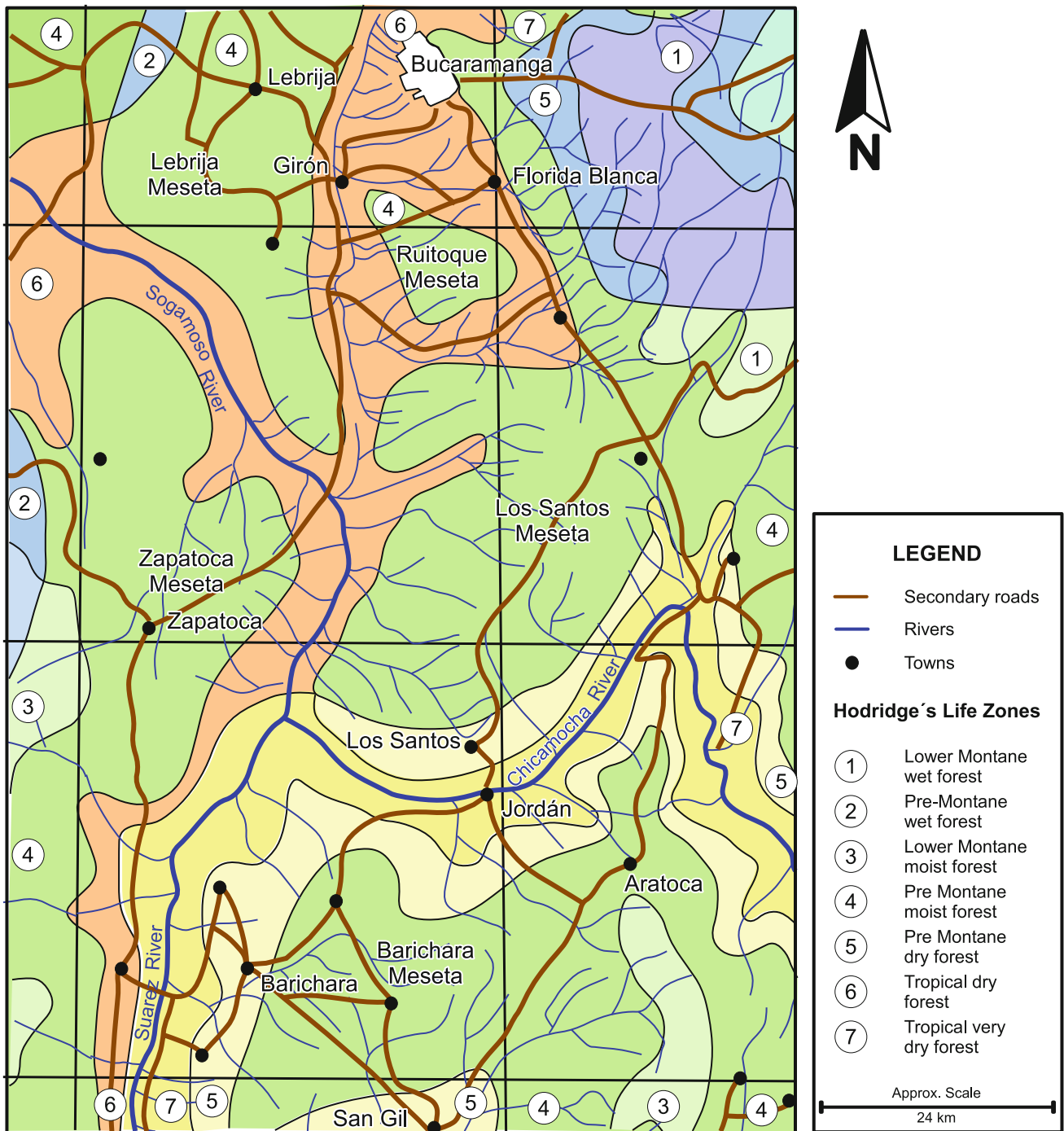
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## 6.2 Climate

The climate of the area is strongly affected by topography. The expected temperature decrease with altitude is accompanied by relief controlled precipitation, which results in permanently dry and warm canyons and related slopes and much more humid conditions in the mesetas and higher slopes developed in the Santander Massif and other surrounding mountains (IGAC 2007). Following Holdridge classification, average annual rainfall for very dry forest is 500–100 mm and 1000–2000 mm for dry forest. In both cases, average temperatures are higher than 24 °C. For mesetas, average annual rainfall is from 1000

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**Fig. 6.1** Localization and vegetation zones. Drier ecosystems are located in the *bottom* of the canyons (numbers 6 and 7 in the map). Pre-Montane humid forest in the mesetas. Adapted from Espinal (1977)

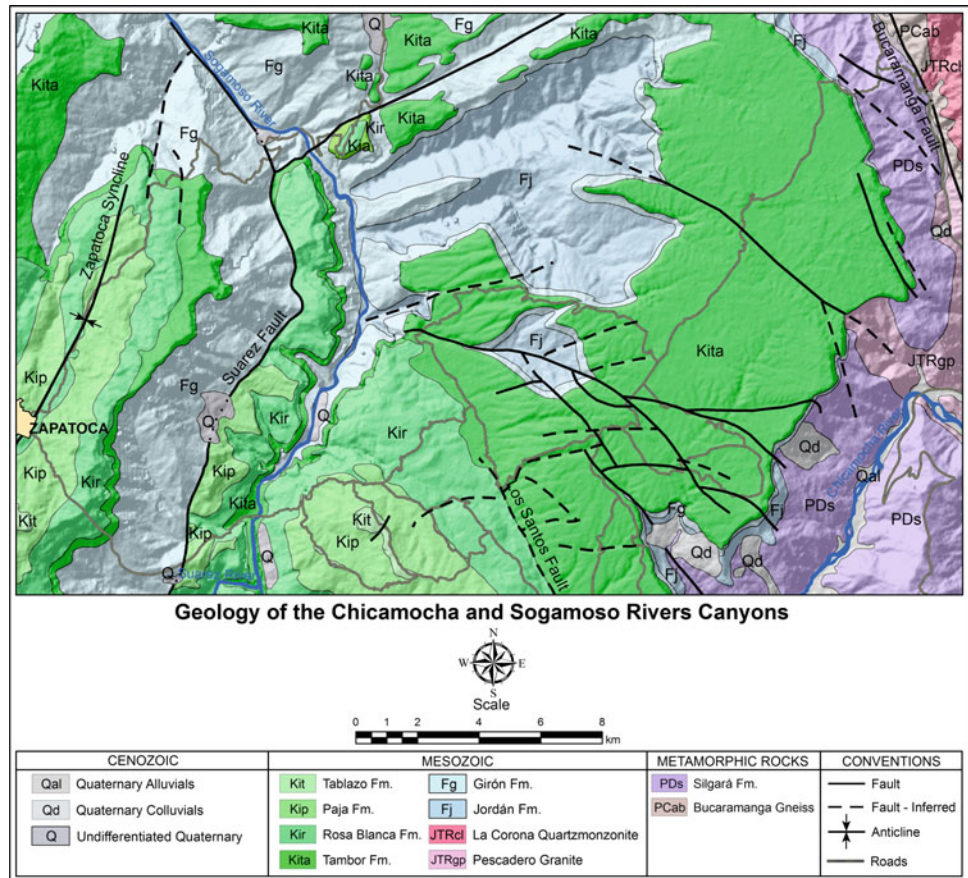
to 2000 mm but evapotranspiration is lower as temperature average is from 20 to 24 °C. (Espinal 1977) Rainfall distribution corresponds roughly to the convergence zone localization: March and April and October–November are more humid than the rest the year.

Natural vegetation is adapted to climate: dry canyons are covered by sub-desertic, xerophytic tropical dry to very dry

forest, characterized by cactus and brushes with very small leaves to prevent evapotranspiration (Fig. 6.3).

Soil are poorly developed in the canyon slopes. Human intervention consisted certainly in the burning of the original vegetation and the introduction of grazing cattle as goat and sheep; these animals proved to be the only species able to survive in such areas, although their impact in some was

**Fig. 6.2** Geology. The major Bucaramanga Fault separates Jurassic and Paleozoic igneous and metamorphic rocks on the east, Jurassic and Cretaceous sedimentary strata on the west, forming the mesetas. Adapted from Ingeominas (1977) and Ward et al. (1969)



particularly drastic, as for instance in lopes developed on igneous and metamorphic rocks (Fig. 6.4), giving rise to practically irreversible erosion phenomena.

### 6.3 Geological Aspects

The Santander Massif (Macizo de Santander) is one of the several old massifs found in the Eastern Cordillera.

It is an igneous–metamorphic complex and its older rocks are Precambrian gneisses, schists, quartzites, orthogneisses, and migmatites. Lower grade metamorphic rocks including phyllites, marbles, and metasiltstones, apparently of Ordovician–Silurian age, are also present, as are the Upper Paleozoic (Middle Devonian–Permian) sedimentary rocks, which present evidence of metamorphism too. During Triassic–Jurassic, igneous activity resulted in the intrusion of several batholiths and other plutons as stocks, which are part of the Santander Plutonic Group (INGEOMINAS 1993) (Fig. 6.2).

The main lithostratigraphic units that have been recognized in the Chicamocha Canyon are as follows:

**Silgará Formation** A low grade metamorphic rock unit of sedimentary origin, composed of micaceous schists, intruded by leucocratic granite, aplites, pegmatites, and dacitic porphyry dykes. It has been assigned a Cambrian–Ordovician age (Ward et al. 1973; Restrepo 1982).

**Pescadero Granite.** It was first described by Ward et al. (1973). Its radiometric age is 193.6 Ma and it constitutes the igneous basement of the mesetas. In the Chicamocha Canyon, it has been described as an igneous rock with textures from porphyritic to phaneritic, which intruded the Silgará Formation to form coarse-grained, pegmatite-like bodies and also as very fine-grained rhyolites, composed of potassic feldspars, quartz, and biotite; pegmatites contain large muscovite plates.

**Jordan Formation** It is formed by greenish-gray, coarse-grained to slightly conglomeratic sandstones, with cross-stratification, intercalated by greenish-gray claystones





**Fig. 6.3** Semiarid intervened vegetation in the Chicamocha Canyon (tropical dry forest); photo was taken after a rain period; during dry season the almost complete loss of the leaves gives to the landscape a more arid aspect (Photo Michel Hermelin)

levels. In the upper part, red-brownish to red-grayish siltstones and medium sized layers of fine-grained sandstones are present. Two thin layers of felsic-welded tuffs have also been described. It was deposited in a volcano-clastic continental environment. The thickness of this formation varies between 300 and 660 m (Ward et al. 1973). It is discordantly overlain by the Giron Formation. On the basis of its stratigraphic relations, the Jordan Formation is considered of Lower to Middle Jurassic age.

**Giron Formation** The Giron Formation can be observed both on the eastern and the western side of the Santander Massif. In both cases, it becomes progressively thinner until it disappears completely (Julivert 1963a, b). In the west, where its outcrops are better preserved, it has been described as a clastic siliceous succession with a characteristic red to purple red color discordantly overlying the Jordan Formation (Cediel 1968).

**Tambor Formation** Its type locality was defined by Cediel (1968) who described this unit as the assemblage of three levels: the lower one, composed of sandstones, mainly arkosic, with frequent reddish color; the middle one, clayey with sandstone intercalations, also of reddish to pink color; and the upper one, made of white sandstone with a stratification better defined than that present in the lower level. This formation was renamed Santos by (Etayo-Serna 1982). The total thickness is of more than 200 m along the western edge of the Santos Meseta and 120 m in the eastern edge. This formation is concordantly overlain by Rosablanca Formation and its contact with Giron Formation is transitional (Fig. 6.5).

**Rosablanca Formation** The Rosablanca Formation stratigraphy was studied in detail in a 318-in-thick succession located in the Sogamoso River Canyon, west of the Santos Meseta, by Zamarreño de Julivert (1963). Its lower



**Fig. 6.4** Surface erosion and rill and gully development on the Silgara Formation in the Pescadero Area. Crystalline rocks appear to be much more susceptible to surface erosion than surrounding sedimentary rocks (Photo Michel Hermelin)

part is composed of limestone and gypsum layers containing oolites, ostracods, and dolomites. The lower part presents evaporite deposits as gypsum and polyhalite, which indicate hypersalinity and quiet sedimentary conditions. Gypsum is presently mined in horizontal tunnels along the Sogamoso River (Fig. 6.7). The rest of the sequence was deposited in a shallow marine neritic environment. Strata show a tabular geometry and are strongly fractured and weathered. The thick limestone layers look bluish gray when fresh, while weathering gives them pale yellow tone. Dark gray tabular layers of calcareous mudstones with diffuse plane lamination and calcareous nodules can be observed in the bottom of the formation, together with dark gray limestones in thick to very thick layers with tabular shape. This formation is concordant with both the underlying Los Santos Formation and the overlying Paja Formation; its age is Jurassic and comprised between Valangian and Lower Hauterivian

(Etayo-Serna 1968; Etayo and Rodriguez 1985) (Figs. 6.5, 6.6 and 6.7).

**Paja Formation** It consists of shale layers, slightly fossiliferous, containing septaria and calcite veins (Julivert 1958). It was described by Julivert et al. (1964) as lutites with gypsum and calcareous nodules. Its thickness varies between 125 and 625 m. In some of the mesetas, red fissile mudstone can be observed to occur in thick layers with notorious plane parallel lamination and gypsum plates filling fractures parallel to stratification, intercalated with tabular layers of black marl.

**Tablazo Formation** The sequence of this unit consists of gray to black, fossil-bearing limestones, locally containing glauconite and black clays. These are intercalated with horizons of gray to bluish gray, fossiliferous claystones in medium to large layers with subordinate gray, fine to medium grained sandstones, and slightly calcareous clays in thin





**Fig. 6.5** South eastern flank of Los Santos Meseta. Vertical scarp corresponds to the Tambor-Los Santos Formation sandstones underlain by a thin layer of Giron Formation. The lower slope is Silgara Formation and slope deposits (Photo Michel Hermelin)

layers (Wheeler, in Morales 1958). The sedimentary environment seems to correspond to shallow, neritic conditions. The total thickness varies between 150 and 325 m. The Tablazo Formation shows a concordant contact with the underlying Paja Formation.

**Quaternary deposits** They are found mainly on the Jordan and Los Santos Formation and along the main river banks. Alluvial deposits form terraces containing pebbles and blocks of different compositions and sizes along the Chicamocha and Sogamoso Rivers. Colluvial deposits were emplaced by mass movements mainly along the Chicamocha and Sogamoso River canyons and deposited principally on the Jordan and Los Santos Formations (Carrillo et al. 2003) (Fig. 6.8).

From the structural standpoint, the Chicamocha River canyon affects the part of the Los Santos and Barichara Mesa relief, which expresses the recent structural evolution of the Andean system, showing several types of deformation styles (Julivert 1958). The Mesetas region is limited by two

important features: the Santa Marta-Bucaramanga Fault System, which uplifted the Bucaramanga Massif and the Suarez fault, with a N–S orientation parallel to the Suarez River and partially to the Sogamoso River. This fault divides the Mesetas region in two second-order structural units: the western one formed by the Lebrija Meseta and Zapatoca Massif and the eastern one which includes Bucaramanga, the Ruitoque and Los Santos Mesetas and the Barichara-Curiti-San Gil area.

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## 6.4 Geomorphological Evolution

The Chicamocha River Canyon is the result of fluvial erosion favored by the presence of faults that weakened the rock and permitted the excavation of deep valleys with steep slopes. Julivert (1958) signaled that the region's most notorious morphologic characteristics is the platform aspect





**Fig. 6.6** The lower, vertical slope was cut in the Tambor-Los Santos Formation (from river to **a**). The inclined, stratified part corresponds to the Rosablanca Formation (**a, b**). The *upper part* belongs to the Paja Formation (Photo Michel Hermelin)

of all the units: these remnants are nothing else than fragments of an older continuous plain (Fig. 6.9a). Formed probably since Early Cenozoic in the graben comprised between Suarez and Bucaramanga Faults which was later excavated by the ancestors of the present rivers: Chicamocha, Suarez and Sogamoso (Fig. 6.9b). Los Santos and Barichara Mesas form structural surfaces. Each one of the mesetas has developed a complex hydrographic network which is the beginning to excavate its drainage consisting in meandering streams with longitudinal profiles showing a relatively advanced evolution. All these streams have falls of 800–100 m to reach the Chicamocha and Suarez Rivers (Julivert 1958). According to this author, the canyons are gorges broadened by the long fluvial erosional activity.

The capture of Chicamocha river, which originally flew along the Bucaramanga fault, by an affluent of the Suarez-Sogamoso River part and that of the Sogamoso by an affluent of the Magdalena River flowing toward the North West complete the evolution (Fig. 6.9c). With respect to the chronology, Julivert (1958) considers that the

movements which created the depressed areas between Bucaramanga Suarez Faults began in late Cenozoic. The area remained relatively flat until the Pliocene cordillera uplift which reactivated the river excavation to produce the canyons.

Within the Chicamocha Canyon, areas with homogeneous relief can be recognized as product of the interaction of meteorological, geological, hydrological, and biological factors. In general, crystalline rocks give rise to moderate slopes (Fig. 6.5, lower part). Jurassic Giron clastic sediments and Cretaceous Rosablanca stratified limestones produce intermediate slopes (Figs. 6.10, 6.6a–b section). Steeper, vertical slope develops on Cretaceous Tambor. Los Santos Formation sandstones. The main landforms identified in the canyon are as follows:

- slopes, remnant hills, scarps, and torrential fans which are generally associated with both erosional processes and structural influences.
- terraces and floodplains related to fluvial processes



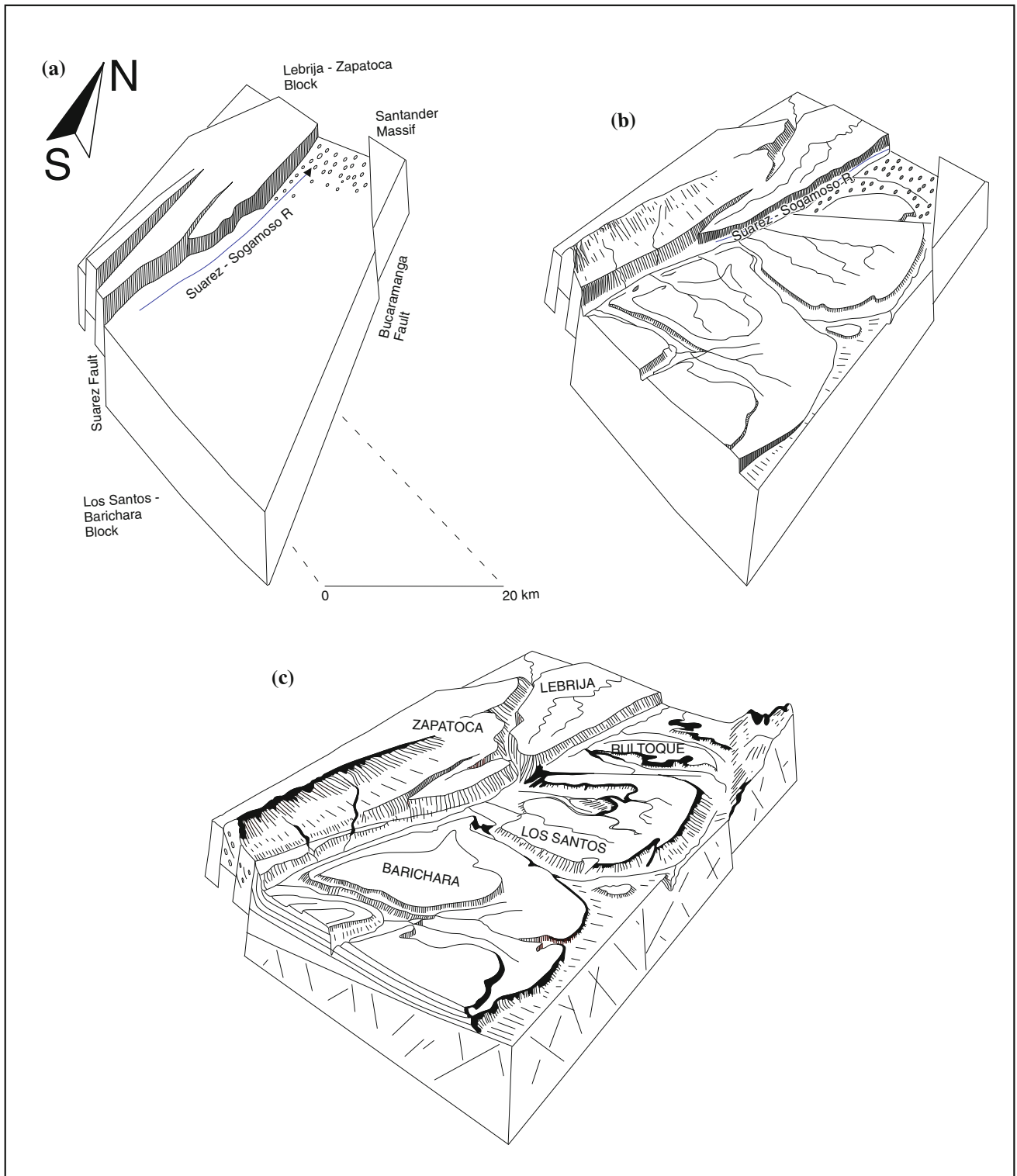


**Fig. 6.7** Cretaceous Rosablanca Formation with tunnels for gypsum exploitation. Most of the mines are in production (Photo Michel Hermelin)



**Fig. 6.8** Poorly cemented and locally heavily eroded Quaternary deposits, Chicamocha Canyon (Photo Michel Hermelin)





**Fig. 6.9** Geomorphological evolution of the mesetas region. Adapted from Julivert (1958) (see text for comments)



**Fig. 6.10** Sogamoso River Canyon carved on Jurassic Giron Formation. A slope deposit is visible on the *left*. On the *right*, stratification is also masked by slope deposits. *Red color* is typical of Giron Formation sediments (Photo Michel Hermelin)

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