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GEOLOGICAL EXPLORATIONS EAST OF THE ANDES IN ECUADOR[1]

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ABSTRACT

An area of 8,000 square miles, lying east of the Andes in Ecuador, was explored in 1921. The old Indian towns of Archidona, Tena, and Napo are in the northern part; Macas, the largest settlement in the Oriental region, is at the southern extremity of the area. Astronomical observations were made as a check on the plane-table traverse, which was carried over all routes of travel. Collections of fossils, mostly from the vicinity of Napo, establish one horizon of Turonian (Eagle Ford–Benton) age, and a second of middle Albian (mid-Comanchean) age. Unfossiliferous red beds occur above this Cretaceous section, and below it are sandstones and volcanic rocks. The Napo Cretaceous beds are petroliferous. Cretaceous rocks east of the Andes have been described from Colombia, Venezuela, Peru, Bolivia, and the Argentine Republic, but this is the first description of such rocks from eastern Ecuador.

INTRODUCTION

BASIS OF THE PAPER

This paper presents an account of observations made by the authors while engaged in geological work in eastern Ecuador for the Leonard Exploration Company, through whose courtesy it is published. Five months during the latter part of the year 1921 were spent in the field.

HISTORY OF EXPLORATIONS

So energetic was the Spanish conquest of Peru that seven years after the execution of Atahualpa, the last Inca king, the Spanish sent an expedition into what is now eastern Ecuador. Gonzalo Pizarro, brother of

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Francisco Pizarro, the famous conqueror of Peru, marched northeast from Quito in February, 1541, descending the valley of the Rio Coca. Although many died from famine and disease, a few men under Orellana drifted down the Napo and Amazon to the Atlantic.

Many since that time have crossed this area: travelers, explorers, and priests. The striking thing about all these journeys is the small amount of geographic knowledge and the entire lack of geologic knowledge recorded.

Alexander von Humboldt,[1] who journeyed in the Andean Highland in 1801–2, climbed the volcanic peaks around Quito but did not descend the eastern slopes of the Andes. He is the first, however, to record Cretaceous rocks in the Andean highlands.

In 1867 James Orton of Rochester, New York, made a trip across the Andes from the Pacific side and descended the Rio Napo to the Amazon and thence to the Atlantic. He published an account of his trip in book form,[2] and also a record of his physical observations[3] which were of great scientific value. He carried two mercurial barometers, a Wollaston boiling-point apparatus, and thermometers.

The best map of Ecuador was prepared by Theodor Wolf, a German, who taught for thirty years at the University of Quito. In 1892 his map was published in Leipzig at the expense of the Ecuadorian government. A small-scale edition in atlas form was prepared by Felicísimo López in 1907.

The authors have previously published a map[4] of the area explored by them. It is the first map of this area based on a plane-table survey. It shows for the first time the exact location of the volcanic peak of Sumaco and the details of the Rio Napo from the town of Napo to the mouth of the Rio Coca.

ACKNOWLEDGMENTS

Dr. José Louis Tamayo, president of Ecuador in 1921, received the writers in Quito and gave them letters to government officials and others which were of great assistance in traveling through the Oriental region.

[1] Alexander von Humboldt, "Geognostische und Physikalische Beobachtungen über die Vulkane des Hochlandes von Quito," *König Preuss-Akademie der Wissenschaften Berlin*, Verhandlungen, February 9, 1837.

[2] James Orton, *The Andes and the Amazon* (New York: Harper Brothers, 1870), 356 pages.

[3] James Orton, "Physical Observations on the Andes and the Amazon," *American Journal of Science*, Vol. 46 (New Haven, 1868), pp. 203–13.

[4] Joseph H. Sinclair and Theron Wasson, "Explorations in Eastern Ecuador," *Geographical Review*, Vol. 13 (April, 1923).

Mr. Nicolas G. Martinez, of Ambato, arranged for the special train from Ambato to the end of the railroad line at Pelileo. He also furnished copies of maps of the Curaray Railway Survey which were used in starting the surveys east of the Andes. Mr. Manuel I. Rivadeneyra, of Napo, furnished Indian carriers and acted as interpreter among the Indian tribes. The success of the expedition was partly due to his good management. Governor Burbano de Lara, of the Oriental region, gave official welcome to the party at Tena. The Dominican Fathers at Canelos will always be remembered for their hospitality and assistance, as will also the government officials and town council at Macas under the command of Manuel J. Bejarano. The end of the journey at Riobamba was made pleasant by the friendly welcome of Colonel Enrique Rivadeneyra. Special mention should be made of the assistance of representatives of the Leonard Company in Ecuador.

THE AREA EXPLORED

The area explored (Fig. 1) lies east of the Andes between 0° 30′ and 2° 30′ south of the equator and between meridians 77° 00′ and 78° 10′ west of Greenwich. This area extends approximately 100 miles eastward from the foot of the Andes and 170 miles north and south. The old Indian towns of Archidona, Tena, and Napo are in the northern portion of the area. The town of Macas is at the southern extremity.

ROUTE OF TRAVEL

Entrance to the region was from the Pacific seaport of Guayaquil by rail over the American-built railroad to Ambato, which is on the main railway line between Guayaquil and Quito. Ambato is on the central plateau of the Andes, 196 miles by railroad from Guayaquil, and is 8,435 feet in elevation. At Ambato another railway line was followed to its terminus at Pelileo, 21 miles east. Here Quechua Indians from the Oriental region transferred all baggage to back packs, and the journey down the Rio Pastaza was resumed on foot. At Mera on the Rio Pastaza, 56 miles east of Ambato, the survey was started. It followed an obscure Indian trail northeastward to the valley of the Rio Anzú, which was descended to Napo, a small settlement on the Rio Napo, 48 miles from Mera. Here headquarters were established for the exploration of the northern portion of the area. From the town of Napo a stadia survey was made down the Rio Napo to the mouth of the Rio Coca, a distance of 98 miles.

Returning to Napo, the expedition traversed the Papallacta trail, which is the old route from Quito to Napo, with side trips on the rivers which were crossed. This trail was followed a distance of 29 miles from

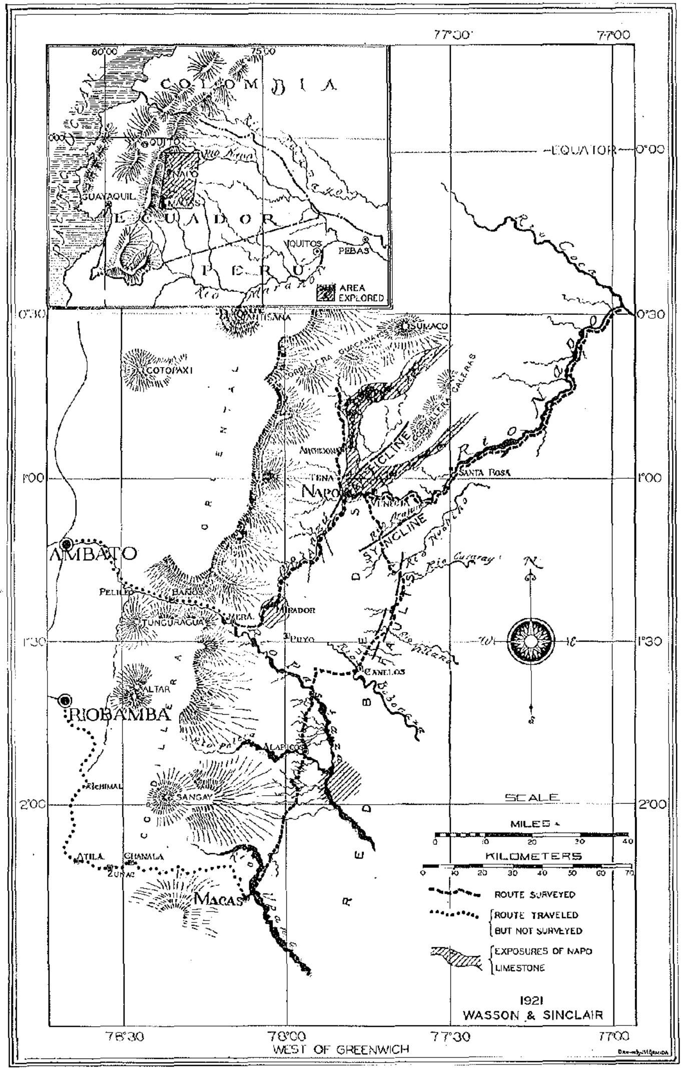


FIG. 1.—Inset shows location of area explored along the eastern base of the Andes in Ecuador. Large map is the area explored made from plane-table survey. The route surveyed and principal geological features are shown.

Napo to the foot of the Cordillera Guacamayos, a low spur running east from the Andes. After another return to Napo, a trail was cut and surveyed southward through the forest to Canelos on the Rio Bobonaza, 56 miles from Napo. Then the traverse continued southward from Canelos on old Indian trails across the Rio Pastaza to Alpicos on the Rio Palora, and farther south to Macas on the Rio Upano, 126 miles by traverse measurement from Napo. At Macas the surveys terminated and the return to civilization was made up the Rio Upano to its headwaters at the summit of the Andes (map, Fig. 1) and down an affluent of the Pastaza to the railroad at Riobamba, a city on the Andean plateau, 35 miles south of Ambato, the starting-point. The approximate distance covered on foot and by canoe, counting some back-tracking in the vicinity of Napo, was 600 miles.

METHODS OF SURVEY

In the absence of any accurate map of the Oriental region, the boundaries of the concessions examined had been defined in terms of latitude and longitude. In order to locate these the expedition carried, besides the Gurley alidade and plane-table outfit, two accurate watches and an engineer's transit with vertical arc, with which observations for azimuth, latitude, and longitude were made.

The two watches were compared with the ship's chronometer on the voyage from Panama to Guayaquil, and one was set to Greenwich mean time and accurately rated for daily variation. These watches were carefully packed and transported across the mountains. At Mera the first observation was made on the sun at noon for longitude, but clouds prevented any check by star observations. Repeated observations on the sun established the longitude at Napo as 77° 49′ west of Greenwich. Observations for longitude at other places were not taken because of the increasing errors in the time carried by the watches, but this was unnecessary, as all other points were tied to Napo by the plane-table traverse.

Latitude was determined at Napo, the mean of many star observations being 1° 03′ south. At other points along the survey where weather conditions permitted, observations were made for latitude as a check on the plane-table traverse.

Starting at Mera where the Rio Pastaza emerges from the Andes, a plane-table traverse was run over all the route as far as Macas. A 300-foot cotton tape coated with paraffin was used on the forest trails. A new tape was made every week. Direction was obtained by sighting on the position of the man ahead as determined by the sound of his voice. Corrections for lack of alignment of the tape were made on the ground. On open rivers like the Napo a more accurate survey was made by the stadia method with the plane table and telescopic alidade.

The survey of the route of travel was mapped on a scale of 1:48,000. A smaller map on a scale of 1:480,000 was also constructed in the field in order to triangulate the mountain peaks. A simplified form of this map is the one published in Figure 1.

Elevations were established with aneroid barometers. The curves of daily variation which were made at several points along the route of travel showed very uniform atmospheric conditions from day to day. High barometer at nine in the morning is followed by a slowly falling barometer until four in the afternoon, when the maximum low is reached. This maximum low is generally followed by a gentle rain which falls for two or three hours. Barometric curves at several points in the area are so nearly alike that the same correction table can be used for all stations.

PHYSIOGRAPHIC DIVISIONS OF THE ROUTE

PACIFIC COASTAL PLAIN

In order to reach the Amazon plain in which explorations were carried on, the Pacific coastal plain and the Andes Mountains were crossed. The coastal plain is about 50 miles wide, is low-lying, and is covered with tropical vegetation, with the exception of plantations of sugar cane and cacao here and there. The streams are short and torrential, emerging suddenly from the Andes where they drop débris in the form of alluvial fans and cones. Over the lowlands they are sluggish and muddy, following meandering courses.

Guayaquil is the only large seaport in Ecuador. It is situated on the Rio Guayas near its junction with the Gulf of Guayaquil, which is virtually an estuary of the Rio Guayas. From Guayaquil the railroad crosses the coastal plain and then abruptly rises to the summit of the Andes at an elevation of 10,000 feet. A vertical distance of about 9,000 feet is negotiated by rail in 20 miles of direct line, although the course of the railroad is several times that distance. The vegetation changes suddenly at about 6,000 feet from tropical to semi-arid.

ANDES MOUNTAINS

The Andes Mountains consist of a plateau about 9,000 feet in elevation, from which rise many volcanic peaks. These have been described as forming an eastern and western cordillera, but topographic studies show no such regularity. These peaks, however, divide the plateau into basins, in one of which lies the town of Ambato. The plateau region is treeless and semi-arid, and the volcanic peaks are covered with perpetual snow. On the lower slopes of the mountains there are considerable areas under cultivation, and some of the bottom lands are irrigated. The climate is temperate and much fog exists at certain seasons.

The Ambato basin is drained by rivers flowing into the Amazon. The Rio Patate flowing from the north, and the Rio Chambo from the south, unite near Baños to form the Rio Pastaza. Both these tributaries are of moderate size, and at the junction where they join to form the Pastaza they are deeply intrenched in volcanic ash.

The most prominent characteristic of the Andean uplift in Ecuador is its narrow base and precipitous sides, the mass being less than 90 miles wide at the base and 40 miles wide at the top. The plateau summit is about 9,000 feet in elevation and from this general level rise volcanic cones to elevations of 18,000 and 20,000 feet. Among the more prominent peaks are Chimborazo, Cotopaxi, Tunguragua, and Sangay, the cones of Cotopaxi and Sangay being particularly symmetrical. The sides of the volcanic peaks are covered with extrusive volcanic débris, much of the material on the plateau at their base being in the form of pumice. The general aspect of the slopes of these volcanic peaks gives the impression of very recent volcanic activity.

THE PASTAZA VALLEY

The Rio Pastaza formed by the junction of the Chambo and the Patate, 25 miles east of Ambato, flows due east, cutting deep into the eastern slope of the Andes, and is a natural route of travel from the highlands to the Amazon plain. The valley is deeply intrenched in volcanic débris east of Ambato, and on the northern slopes of Tunguragua is cut through recent lava flows. From the junction of the Chambo and Patate, at an elevation of 6,300 feet, the river descends to 3,800 feet at Mera, 31 miles further east, where it emerges from the wall of the Andes. Five miles east of Baños is Agoyan Falls, 200 feet high, where the river plunges over a lava bed. Below these for several miles small waterfalls enter the gorge through hanging valleys.

The Pastaza as it emerges from the mountains changes into a braided stream of swift current, in time of flood transporting much material. Great boulders are carried or rolled along the bottom and their grinding can be heard some distance from the stream. After leaving the Andes the Pastaza flows southeastward across the south-central part of the area under discussion to join the Amazon, 250 miles west of Iquitos, Peru. Looking from a point on the east slope of the Andes out on the lowland extending eastward from the base of the mountains, one gets the impression, aided by the thick forest cover, of a uniformly sloping smooth plain. An examination of this, however, shows it to be a region which for 100 miles from the base of the Andes slopes from 4,000 to 1,000 feet above the sea and is made up of more or less dissected interstream areas and river valleys, some of which are 1,000 feet below the interstream summits.

GEOGRAPHY OF THE REGION EXPLORED

DRAINAGE

The region explored on this eastward-tilted plain may be divided into a northern and a southern area, such division being made on the basis of the two main lines of drainage. The northern area is drained by the Rio Napo and its tributaries. The Rio Anzu, the principal tributary of the Napo, flows from the vicinity of Mera, 40 miles northeast, to the village of Napo, where it joins the Rio Napo. All previous maps showed this river as flowing due east from the foot of the Andes. The Rio Napo has its source in the belt of heavy rainfall, and is a torrential stream subject to sudden floods. At Napo the river is 300 feet wide, with banks of limestone. Below Napo the stream becomes progressively wider, with many side channels, the banks being lower and made of alluvium. In this lower section the stream is excessively braided due to the lessened gradient and to the material carried in flood time, which, as the current slackens, is deposited in the channels, forcing the water to find new courses. At the junction with the Coca the Napo is 2,000 feet wide and here flows in a single channel, is more sluggish and meandering, carrying mud and silt rather than sand and gravel.

The area explored north of the village of Napo is drained by the southward-flowing Misahualli and its tributaries, the Jandachi and the Hollin. These streams are all similar to the upper course of the Napo and all drain into it. The northern boundary of this area is formed by a mountain ridge, the Cordillera Guacamayos, extending eastward from the Andes as a spur. A few miles east of the termination of the Cordillera Guacamayos stands Cerro Sumaco, an isolated volcanic peak with an elevation of about 12,700 feet, which seems to rise out of the Amazon lowland. This peak was located and its elevation determined for the first time by this expedition. Also in this area north of the Napo is the Cordillera Galeras, whose peaks were located by triangulation from the Rio Napo survey. They rise to an elevation of approximately 6,000 feet. They were not explored.

The two principal southern tributaries of the Napo, the Arajuno and the Curaray, were crossed during the survey from Napo to Canelos. These streams rise near the headwaters of the Anzu in the highlands east of Mera. Their courses were not surveyed, but where crossed they are small, clear streams in well-defined channels. The stream divides rise to nearly 1,000 feet.

The southern area is drained by the Rio Pastaza, which, as previously noted, flows southeastward after emerging from the Andes at Mera. Its northern tributaries, the Villano, Bobonaza, and Pindo, all rise in the high land east of Mera. At the mouth of the Rio Pindo the Pastaza is a rapid stream about 600 feet wide at low water. South of the Rio Pastaza the first tributary is the Rio Palora, which at Alapicos is a rapid stream flowing between banks 100 feet high. Between Alapicos and Macas the trail surveyed passes close to the base of the Andes and through a region of torrential rains. Many small, rapid streams flowing eastward were crossed. They carry no sediments, but flow over grassy slopes between low banks. The sheets of water have not collected into well-defined channels.

The trail from Macas to Riobamba on the Andean plateau followed the Rio Upano to its source in lakes high in the Andes. The river is in a deep gorge on the eastern slope of the Andes, and, like the valley of the Pastaza, makes a natural route from the highlands into the Oriental region.

FORESTS

The forests are limited entirely to the lower slopes of the Andes and to the lowlands at the east. The highlands of the Andes, due to the lack of rainfall, are treeless and are called *paramos*. No breaks occur in the extensive forests east of the Andes except in the neighborhood of the small settlements where a few acres are cleared.

CLIMATE

The rainfall is exceptionally heavy on the east slope of the Andes, but light on the plateau. Its greatest amount occurs on the immediate east wall of the mountains, where the moisture-laden air begins to ascend. What precipitation reaches the lofty elevations of Chimborazo and other peaks which rise more than 20,000 feet above the sea occurs as snow and ice. Extensive glaciers and snow fields are located on Antisana, Chimborazo, and other peaks. The snow line is about 15,000 feet above sea-level. The rainfall at Puyo at the eastern base of the Andes, at an elevation of 3,200 feet, has been estimated at 150 inches per year.

In the area explored east of the Andes between elevations of 1,400 and 2,000 feet the temperature ranged from 66° to 82° Fahrenheit.

INHABITANTS

The Andean plateau is well populated; the Amazon lowlands have very few inhabitants. The Indian aborigines east of the Andes form the main part of the population. The Indians north of the Pastaza live close to the few white settlements and speak the Quechua language. South of the Pastaza dwell Indians who are entirely independent of white masters and speak the Jivaro language. The latter are noted for their head-hunting customs, which have been described by several writers.[1]

SETTLEMENTS

Settlements in the Oriente are few and located along streams, which are the chief means of communication. The settlements consist of a few white families who have the loyalty and service of many Indians living close by. At Napo there are four houses inhabited by white Spanish-speaking people, among whom is Manuel Rivadeneyra, a true pioneer. It was once a mission station with a larger population. Tena, 4 miles north of Napo, is somewhat larger, since it is the headquarters of the governor of the Oriente. Archidona, near Tena, was founded soon after the Spanish conquerors arrived in Ecuador and became the headquarters of the early missionaries. Canelos is the principal settlement between the Napo and the Pastaza. It was also founded as a Catholic mission shortly after the Spanish conquest of Ecuador. Today, after several periods of abandonment, it is again a mission center with two Dominican fathers in charge. Macas, located in the southern part of the area, is much the largest town in the Oriente, having a population of about 600. In 1921 it had a Protestant mission in charge of Mr. and Mrs. Oleson, and a Catholic mission. The village of Macas is so isolated, one wonders at its existence. There is no other settlement between it and the top of the Andes. It takes seven days of tedious traveling on foot along muddy trails to reach the nearest settlement on the upland.

The Indians have no villages as such. The Jivaros approach more closely a social organization in that sometimes they live in large houses containing several families.

STRATIGRAPHY

ANDEAN CRYSTALLINE ROCKS

The trail down the Pastaza from Ambato to Baños passes through a region of recent volcanic activity, and most of the surface exposures are made up of extrusive material. Near Pelileo some rhyolite was observed.

[1] F. W. Up De Graff, *The Head Hunters of the Amazon* (New York, 1923), 337 pages.

From the junction of the Chambo and Patate to Baños the south wall of the Pastaza canyon is made up of lava flows from the volcano Tunguragua. In some places basaltic columnar structure is well developed. Schists, gneisses, and granites are exposed along the north side of the river above Baños to Mera. Granites and rhyolites occur above Mera. These rocks, which form the core of the Andes of Ecuador, were not studied in detail. They are unquestionably older than the sedimentary series east of the mountains.

NAPO REGION—SEDIMENTARY SECTION

The best sedimentary section exposed in the area is in the vicinity of Napo. The beds outcrop in an area whose dimensions are 25 miles north and south by 10 miles east and west, and whose elevations range from 1,500 to 2,000 feet. The outcrops are along streams where the forest cover has been cut away by stream action. In the absence of any geological information on the region, notes were taken on all rocks examined and collections of fossils were made. As the work progressed it was possible to make up a column and determine age and extent of beds.

MISAHUALLI BASALTS AND TUFFS

The lowest rocks observed in the Napo region are on the Rio Misahualli, 6 miles east of Tena. They consist of basalts and altered extrusive igneous rocks overlain by tuffs. The basalt is predominantly green or dark brown, and in its altered condition has the appearance of sedimentary rock. The greatest thickness observed is about 150 feet. These igneous extrusives probably represent local flows interbedded with the sediments. The tuffs overlying the basalt are gray and pink in color and are in sharp contrast to the overlying sandstone. The thickness was not determined, but it is probably not more than 100 feet.

HOLLIN SANDSTONE

Overlying the basalts and tuffs of the Rio Misahualli is a clean, fine-grained quartz sandstone with a thickness of 400 feet. It is well exposed along the Rio Hollin, where cliffs more than 100 feet high are found. No basal conglomerate was found at the contact with the underlying igneous rocks; neither was there any inclusion of igneous material in the overlying sandstone. Near the confluence of the Rio Tena and the Rio Hollin is a thin bed of unfossiliferous black shale near the middle of the sandstone. The exposures of Hollin sandstone are near the axis of the Napo anticline, where only basalts and tuffs were seen to underlie it. It is probable that the igneous rocks are local flows and that older sedimentary beds exist beneath them.

THE NAPO LIMESTONE

Overlying the Hollin sandstone is a series of limestones and black shales 1,500 feet thick. The forest cover makes the estimation of thickness very difficult. The best section of these beds exposed in the area is along the Rio Napo eastward from the town of Napo. From the crest of the low anticline just west of the town beds of limestone and shale dip 6°–10° E. The strike is N. 45° E. At some places the Rio Napo flows along the strike of the beds. A thick limestone member outcrops from the crest of the anticline just west of Napo to a point one mile downstream (Fig. 2), where black shales are found overlying it. This limestone is dark gray and highly fossiliferous, at places being almost a shell conglomerate. It weathers into large blocks. The lower beds merge into a shale which is exposed at low water on the anticlinal axis just west of Napo. Here a bone bed is found carrying fish vertebrae and teeth along with ammonites. This bone bed is the lowest exposure in the Rio Napo section. The black shales carry many fossils, the most prominent being *Inoceramus labiatus*. Flat lens-like inclusions of limestone are in the upper layers of this shale. The highest Napo limestone beds are 6 miles below Napo, at the rapids called Molino de Latas. Here they dip into the river and a short distance downstream they are covered by red beds.

Other sections of the Napo limestone were studied north of Napo (Fig. 3). The contact of the Napo limestone with the underlying Hollin sandstone is seen about 5 miles east of Tena, along the Rio Tena and along the Rio Hollin east of Archidona. The black shales are also exposed east of Tena. The section along the Rio Tena is on the west flank of the anticlinal axis, which passes just west of the town of Napo.

The age of the Napo limestone has been determined, from the fossils collected, as middle Comanchean to Upper Cretaceous, middle Albion to Turonian of the European section. These fossils are largely of Turonian age, equivalent in the United States to Eagle Ford or Benton of the Texas and Rocky Mountain sections, respectively. John B. Reeside, Jr., who examined these fossils, called attention to Albian forms comparable to the mid-Comanchean or Fredericksburg of Texas occurring below the Turonian without any evidence of Cenomanian between. It is possible that Cenomanian beds exist, but that no fossils were collected from them.

The best Albian fossils came from the Rio Hollin, east of Archidona, from beds just above the Hollin sandstone. The Napo beds all yield Turonian forms, the highest Turonian coming from limestone beds east of Morales' house on the trail from Archidona to Quito. A collection of

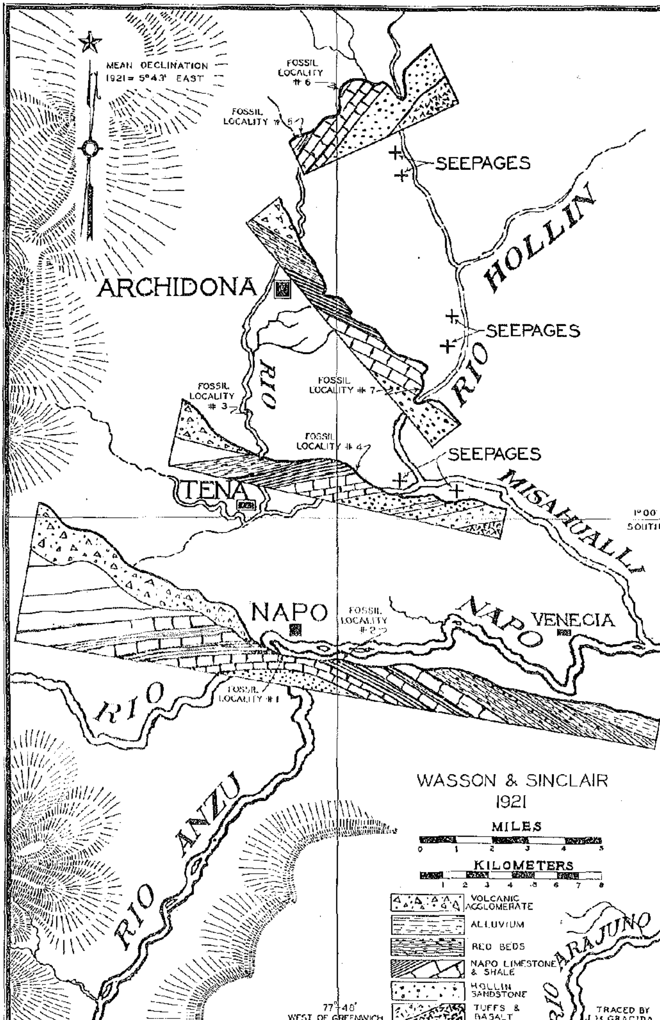


FIG. 2.—Map of the Napo area showing sections of the Napo limestone, fossil localities, and seepages.

fossils from the trail crossing Ursuyacu Creek, $9\frac{1}{2}$ miles north of Napo, shows Albian forms, but field evidence was lacking to show the relation of the highly tilted shales of this locality to the rocks of the Napo and Archi-

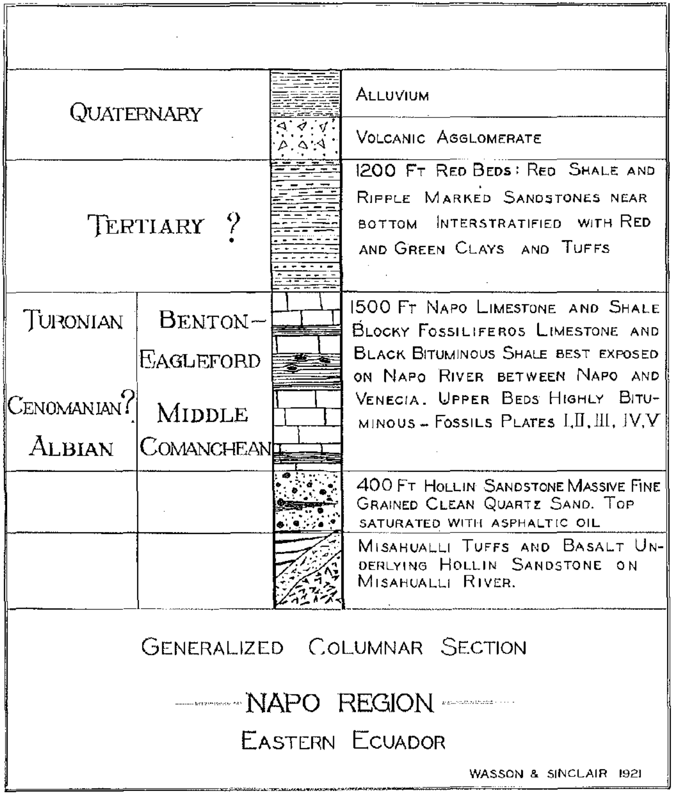


FIG. 3.—Refer to Plates 9, 10, 11, 12, and 13 for fossils.

dona areas. Further work in the region may make it possible to divide the Napo limestone into separate formations. For the purposes of this first report the Napo limestone is understood to represent the limestones and black shales which lie between the sandstone of the Rio Hollin and the red beds at Venecia on the Rio Napo. It is interesting to note that

James Orton[1] referred to the Napo rocks as "dark slates gently dipping east," and made no mention of the Cretaceous fossils (Fig. 4).

Fossil localities.—Fossils of the Napo limestone were collected from the following eight localities (Fig. 2):

1. An outcrop of shales and limestones on the left bank of the Rio Napo about $\frac{1}{4}$ mile above the village of Napo at the crest of the broad anticline, where the strata are nearly flat and unquestionably in place.

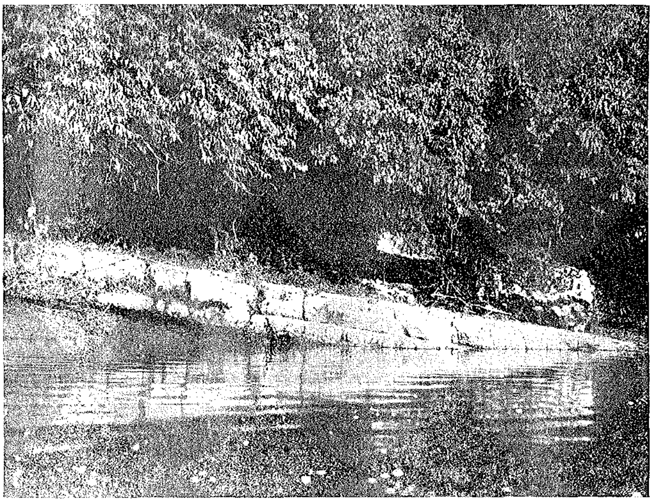


FIG. 4.—Napo limestone dipping downstream, located on the bank of Rio Napo

2. Left bank of the Rio Napo, 1 mile below the village of Napo, from black shales and limestones in place and striking N. 45° E. and dipping 8° SE.

3. The Rio Misahualli, about 2 miles above its confluence with the Rio Tena.

4. In the Rio Misahualli, between the mouth of the Rio Tena and the mouth of the Rio Hollin, where black shales and limestones occur partly in place and as great blocks fallen down into the narrow canyon from the cliff walls.

5. Trail leading east from the Quito road at the house of José Morales, north of Archidona, to the Rio Jandachi (locality 6). The specimens were from a yellow sandy horizon near the top of the Napo limestones. Locality is $1\frac{3}{4}$ miles northeast of Morales' house.

[1] James Orton, *The Andes and the Amazon* (New York: Harper Brothers, 1870), p. 199.

6. Rio Jandachi, six miles northeast of Archidona in a narrow canyon with vertical cliff walls. Horizon should be near the base of the Napo limestones as the underlying sandstones form cliffs at the water surface.

7. Rio Hollin, 3 miles southeast of Archidona, about ½ mile below a seepage of tar in the river bed at the base of a cliff. At this locality the canyon is very narrow with nearly perpendicular walls. The blocks of limestone from which collections were made represent horizons in the cliffs.

8. Quito trail at the crossing of Ursuyacu Creek, 9½ miles north of Archidona.

REPORT ON THE FOSSILS

John B. Reeside, Jr., of the U. S. Geological Survey, examined the fossils collected and made the following report, accompanied by the illustrations shown in the succeeding plates. The fossils examined are deposited in the U. S. National Museum at Washington.

This collection of fossils contains a good representation of two very distinct Cretaceous faunas, one of Turonian age and one of middle Albian. The Turonian fauna in turn is represented by what I take to be two facies, for while the species and the matrix differ, the age is not very different.

The fauna in a hard limestone from the vicinity of the village of Napo (Fig. 2, localities 1 and 2) is composed of species universally accepted as characteristic of the Turonian, equivalent in a general way to that of the Eagle Ford shales of the Gulf region and the Benton formation of the western interior of North America. A very similar fauna is known from Peru, Colombia, and Venezuela.

The fossils in the hard gray limestone from the localities on Rio Misahualli (localities 3 and 4) include Albian and probably Turonian.

The small lots in gray limestone from Rio Jandachi I believe to be Turonian.

The large lot in a yellow sandy matrix that looks like a leached calcareous rock, from the locality on the trail east of the house of José Morales (locality 5), I judge also to be Turonian. There are several species present whose closest relationships are with characteristic Turonian forms, though a few have close relations with Cenomanian or Senonian species. Others are long-ranging and not definite in their testimony. The lot has only one species in common with those from the vicinity of Napo and differs much in lithology, but there can hardly be any great difference in age.

The lots from Rio Hollin southeast of Archidona (locality 7), are mostly in a dark-gray hard limestone and contain chiefly species universally accepted as characteristic of the Albian, particularly the ammonites. Some authors have called this fauna Vraconian, or late Albian, but Vraconian is better restricted to the very latest zones of the Albian. The genera *Brancoceras* and *Oxytropidoceras* are middle Albian. *Oxytropidoceras* is found in the Fredericksburg group of Texas. There are, however, also several specimens of black shale and gray limestone with characteristic Turonian species, showing that both the

Albian and Turonian horizons are present in the section. The Albian zone is equivalent to some part of the middle Comanchean of the Gulf region of North America, and its fauna is well known at many localities in Peru and Colombia.

The lot from Ursuyacu Creek at the crossing of the Quito-Napo road (locality 8) appears to be Albian, though I do not feel certain of the age in view of the absence of the more distinctive species.

The lot without specific locality assignments contains both Turonian and Albian species.

As these statements indicate, the Napo limestone series includes at least two very distinct elements: one of Turonian age and one of Albian age. Between them should lie any deposits representing Cenomanian time. Some of the fossils included in the lists are known in the Cenomanian; some of them, indeed, are used, at least locally, as diagnostic of it. Most of these species, however, have been identified through a considerable stratigraphic range when their entire geographic distribution is taken into account, and are therefore of doubtful value here. I do not see any clear evidence of the presence of a Cenomanian fauna in the collection in hand, though it might very well be represented in the Napo limestone, and through the unavoidable accidents of collecting not have found its way into the collections.

It is notable that the succession of beds in eastern Ecuador is much like that reported from central Peru. Schlagintweit[1] cites a generalized section in which light-colored marly limestone assigned to the Albian is overlain by a considerable thickness of dark limestone and marl assigned to the Vraconian, overlain in turn by a series of red and yellow crumbly shale and marls with beds of limestone assigned to the Upper Cenomanian. The Albian fauna has much in common with that noted in the present collections. The Upper Cenomanian appears to have a number of species in common with the Turonian fauna listed below from the locality east of José Morales' house, and is very probably of the same age. It is worthy of note that some of the age assignments made in the literature dealing with South American geology are not well warranted by the fossils on which they are based. These fossils have received names originally applied to European and African species, and while the similarity is usually great, I doubt the validity of carrying most of the names so far afield and basing overpositive age assignments upon them. The confusion thus made possible is shown by Berry[2] in discussing the fauna from a single bed near Huancavelica, Peru, where there occur together fossils previously assigned to European and African species of Aptian, Albian, Cenomanian, and Emscherian age.

The following lists give the species found in the various lots as designated by the accompanying labels:

[1] Otto Schlagintweit, "Die Fauna des Vracon und Cenoman in Peru," *Neues Jahrbuch.*, Beilageb. 33 (1911), pp. 48, 65.

[2] E. W. Berry and J. T. Singewald, Jr., "The Geology and Paleontology of the Huancavelica Mercury District," *Johns Hopkins University Studies in Geology,* No. 2 (1922), pp. 54–56.

1. Left bank of Rio Napo, ¼ mile above the village of Napo at crest of anticline:
   Inoceramus sp. indeterminable.
   Cyprimeria n. sp. aff. *C. excavata* Morton (Pl. 10, Figs. 4–6).
   Coelopoceras n. sp. A. aff. *C. lesseli* Brüggen and *C. springeri* Hyatt (Pl. 9, Figs. 1, 2).
   Coelopoceras sp. undetermined.
1. Napo, near house of Señor Rivadeneyra:
   Inoceramus labiatus Schlotheim.
   Cyprimeria n. sp. aff. *C. excavata* Morton.
2. Left bank of Rio Napo, 1 mile below village of Napo:
   Inoceramus labiatus Schlotheim (Pl. 10, Fig. 1).
   Roudairia intermedia Brüggen (Pl. 10, Figs. 2, 3).
   The fauna above from localities on Rio Napo is Turonian.
3. Rio Misahualli, 2 miles above confluence with Rio Tena:
   Oxytropidoceras (*Manuaniceras?*) *carbonarium* (Gabb) (=*Schloenbachia acutocarinata* Shumard of many authors).
   Middle Albian.
4. Rio Misahualli, between mouth of Rio Tena and Mouth of Rio Hollin.
   Exogyra aff. *E. flabellata* D'Orbigny (Pl. 10, Fig. 12).
   Pecten sp. indeterminable.
   Probably Turonian.
4. Rio Misahualli, below Tena.
   Probably Turonian species.
      Exogyra aff. *E. flabellata* D'Orbigny.
      Pecten (*Neithea*) *quinquecostata* Sowerby.
   Middle Albian species.
      Oxytropidoceras (*Manuaniceras?*) *carbonarium* (Gabb) (=*Schloenbachia acutocarinata* Shumard of many authors).
5. Trail to Rio Jandachi, 1¼ miles east of José Morales' house, which is 4 miles north of Archidona on the Quito-Napo road:

TURONIAN SPECIES

Arca n. sp. aff. *A. archiacana* D'Orbigny (Pl. 10, Fig. 13).
Glycimeris n. sp. (Pl. 10, Fig. 14).
Pinna sp. indeterminable (Pl. 10, Fig. 15).
Gervillia sp. indeterminable (Pl. 10, Fig. 16).
Pteria n. sp. aff. *P. gastrodes* Meek (Pl. 10, Figs. 17, 18).
Exogyra olisiponensis Sharpe (Pl. 11, Figs 1–3).
Exogyra aff. *E. flabellata* D'Orbigny (Pl. 11, Fig. 4).
Trigonia crenulata var. *peruana* Paulcke (Pl. 11, Figs. 5, 6).
Trigonia aff. *T. hondaana* Lea (Pl. 11, Fig. 7).
Pecten (*Neithea*) *aequicostata* Lamarck (Pl. 11, Fig. 8).
Pecten (*Syncyclonema*) n. sp. (Pl. 11, Fig. 9).
Plicatula aff. *P. auressensis* Coquand (Pl. 11, Fig. 10).

Lima? sp. indeterminable.
Modiola aff. *M. socorrina* D'Orbigny (Pl. 11, Figs. 11, 12).
Modiola n. sp. aff. *M. flichei* Peron (Pl. 11, Fig. 13).
Liopistha n. sp. aff. *L. ligeriensis* D'Orbigny (Pl. 11, Figs. 14, 15).
Cardita n. sp. aff. *C. subparallela* Gerhardt (Pl. 11, Figs. 16, 17).
Protocardia appressa Gabb. (Pl. 11, Fig. 18).
Venus n. sp. (Pl. 11, Figs. 19, 20).
Tellina? sp. indeterminable (Pl. 11, Fig. 21).
Mactra? n. sp. (Pl. 12, Fig. 1).
Corbula cf. *C. peruana* Gabb (Pl. 12, Figs. 2, 3).
Gyrodes n. sp. aff. *G. depressa* Meek (Pl. 12, Figs. 4, 5).
Turritella aff. *T. vibrayeana* D'Orbigny (Pl. 12, Fig. 6).
Aporrhais aff. *A. costae* Choffat (Pl. 12, Fig. 7).
Aporrhais sp. indeterminable.
Fusus n. sp. aff. *F. ubaquensis* Gerhardt (Pl. 12, Fig. 8).
Mammites n. sp. (=*Mortoniceras cañaense* Gerhardt?) Pl. 12, Figs. 9–11).

6. Rio Jandachi, 3 miles east of José Morales' house, which is 4 miles north of Archidona on Quito-Napo road:
Astarte sieversi Gerhardt
Exogyra aff. *E. flabellata* D'Orbigny (Pl. 10, Fig. 11).
Probably Turonian.

7. Five miles southeast of Archidona:

MIDDLE ALBIAN SPECIES

Inoceramus concentricus Parkinson (Pl. 12, Figs. 12, 13).
Ostrea sp. indeterminable.
Plicatula aff. P. *gurgitis* Pictet and Roux (Pl. 12, Fig. 14).
Brancoceras n. sp. (Pl. 12, Figs. 15–17).
Oxytropidoceras (*Manuaniceras?*) *carbonarium* (Gabb) (=*Schloenbachia acutocarinata* Shumard of many authors) (Pl. 12, Figs. 18–20.)
Oxytropidoceras n. sp. aff. *O. belknapi* (Marcou) (Pl. 13, Figs. 1, 2).

TURONIAN SPECIES

Inoceramus labiatus Schlotheim.
Cyprimeria n. sp. aff. *C. excavata* Morton.
Exogyra olisiponensis Sharpe.
Coelopoceras n. sp. B. (Pl. 9, Figs. 3–5).

8. Ursuyacu Creek at crossing of Quito-Napo road, between abandoned house of Manuel Lara and the crossing of Rio Jandachi. About 9½ miles north of Archidona:
Exogyra aff. *E. africana* Coquand (Pl. 13, Figs. 3, 4).
Pecten (*Neithea*) n. sp. aff. *P. phaseola* Lamarck (Pl. 13, Fig. 5).
Pecten n. sp. aff. *P. marrotianus* D'Orbigny (Pl. 13, Fig. 6).
Lima n. sp. (Pl. 13, Figs. 7, 8).

Plicatula aff. *P. gurgitis* Pictet and Roux (Pl. 13, Fig. 9).

This fauna appears to me to be Albian, though not conclusive as to age.

8. East of Andes between Rio Napo and Cordillera Guacamayos:

ALBIAN SPECIES

Inoceramus concentricus Parkinson (Pl. 13, Fig. 12).
Ostrea syphax Coquand (Pl. 13, Figs. 13, 14).
Lima n. sp. aff. L. intermedia D'Orbigny (Pl. 13, Figs. 10, 11).
Brancoceras n. sp. same as at locality 7.
Oxytropidoceras (*Manuaniceras?*) *carbonarium* (Gabb) (=*Schloenbachia acutocarinata* Shumard of many authors).

TURONIAN SPECIES

Inoceramus labiatus Schlotheim (Pl. 10, Fig. 7).
Inoceramus sp. indeterminable (Pl. 10, Fig. 8).
Pecten quinquecostata Sowerby (Pl. 10, Figs. 9, 10).

UNASSIGNED SPECIES

Pholadomya? sp. indeterminable.
Venerid pelecypod, indeterminable.
Gastropod, indeterminable.

RED BEDS AND CONGLOMERATES

Overlying the Napo limestone are red beds and conglomerates which extend in a belt from north to south across the area explored. A contact between the Napo limestone and the red beds is well exposed at Venecia, 7 miles east of Napo. Although the bedding appears conformable, the abrupt change from hard, fossiliferous limestone to soft, red sandstones and shales is very marked and may represent an unconformity of some magnitude. No fossils were found in the red shales. The dip is eastward at angles of 6°–10°. Eastward from Venecia the river clays and sands cover these beds in a short distance. West of Napo glimpses of the red beds are seen on the west limb of the Napo anticline. They are here obscured by the overlying volcanic agglomerate. In the vicinity of Tena and Archidona remnants of the red clays are found on the west side of the Napo structure. The thickness of red beds exposed is not great, being about 1,200 feet at Venecia, but the overlapping alluvium probably obscures a much thicker section. South of Napo, near the headwaters of the Rio Arajuno and Rio Curaray, the red beds grade upward into cross-bedded sandstones and conglomerates which carry lignitic wood and cannon-ball concretions. What appears to be the contact of the conglomerates with the red clays was observed on the Rio Anzu', 4 miles south of Napo. These conglomerates may represent local phases of the red beds, and for the purposes of this report will be grouped with them, as no fossils were found which would indicate their age.

West of the belt of outcrop the red beds are overlain by volcanic material, and to the east they are covered by alluvium. The age of these red beds is one of the unsolved problems of this region. They are tentatively grouped as Tertiary.

James Orton[1] made no direct reference to red beds close to the village of Napo, but did mention clay deposits interstratified with lignites which he found at the mouth of the Curaray and at Pebas, 300 miles farther east. Orton referred to his Pebas beds (map, Fig. 1) as of not later than Pliocene age, but it is doubtful whether they can be correlated with the sandstones and conglomerates of the Napo region on the strength of lignitic layers alone.

Red beds of Oligocene age have been identified east of the Andes in Peru. A fragment of a jawbone with well-preserved teeth from the salt gypsum beds which lie above the limestones was found by J. G. Richards at Chiococa, near Chepeza, on Rio Huallaga, Peru, which is 250 miles south of Napo.[2] This was examined by H. E. Anthony.[3] He describes the fossil teeth as those of a tapiroid animal which lived in Oligocene time.

VOLCANIC AGGLOMERATE

Beds of volcanic débris overlie the Napo rocks, in many places obscuring all exposures. This is particularly true in the belt close to the base of the Andes. These volcanic beds are made up of poorly assorted, angular, volcanic fragments among which are round lapillae and bombs.

[1] James Orton, *The Andes and the Amazon* (New York: Harper Brothers, 1870), p. 282. "We came down the Napo and Marañon, and stopped at this place [Pebas]. Here we discovered a fossiliferous bed intercalated between the variegated clays so peculiar to the Amazon. It was crowded with marine Tertiary shells! . . . . It was unmistakable proof that the formation was not drift but Tertiary; not of fresh but of salt water origin.

"The species as determined by W. M. Gabb, Esq., of Philadelphia, are: *Neritina pupa*, *Turbonilla minuscula*, *Mesalia ortoni*, *Tellina amazonensis*, *Pachydon oblique* and *P. tenua*. All of these are new forms, excepting the first, and the last is a new genus. It is a singular fact that the Neritina is now living in the West India waters, and the species found at Pebas retains its peculiar markings. . . . . Interstratified with the clay deposits are seams of highly bituminous lignite; we traced it from the mouth of the Curaray on the Rio Napo to Loreto on the Marañon, a distance of about 400 miles. It occurs also at Iquitos."

[2] J. G. Richards, *Expedition on the Amazon for the Pure Oil Co.*, 1920.

[3] H. E. Anthony, "A New Fossil Perissodactyl from Peru," *American Museum Novitates No. 111*, Op. 21 (New York: American Museum of Natural History, 1924).

Mud flows and landslides frequently occur in these beds. The western half of the area explored, particularly the portion east of the volcano Sangay, is covered with these volcanic agglomerates which in age probably range from late Tertiary to Recent.

STRUCTURE

The great fault which forms the east scarp of the Andes is the major structural feature of this region. Its throw can be roughly estimated by comparing the Cretaceous rocks reported in the mountains at elevations of 10,000 feet or more with those at Napo, which are at an elevation of 2,000 feet. The fault zone is obscured by extrusive volcanic material. The regional dip of the sedimentary rocks in the Oriental region is eastward away from the mountains. Near the mountains the beds dip westward into the fault. This reversal of dip gives rise to anticlinal structures which lie parallel to the mountains.

THE NAPO ANTICLINE

The axis of the Napo anticline lies just west of the town of Napo. The reversal of dip is well shown in black shales and limestones which are exposed along the river. The west dip is 6°–10°, the east dip about the same. The axis of this anticline strikes N. 45° E., passing east of Tena and crossing the Rio Misahualli just east of the mouth of the Rio Hollin. Farther northeast it probably becomes a part of the Galeras mountain uplift, which was not explored. The plunge of the Napo anticline to the southwest is shown by the existence of the Hollin sandstone on the surface near the mouth of the Rio Hollin, while along the Rio Napo it is overlain by several hundred feet of limestone and shale. The axis of the Napo anticline projected southwestward follows the valley of the Rio Anzú. This valley is probably anticlinal throughout its length.

MIRADOR UPLIFT

In the Mirador hills northeast of Mera and near the headwaters of the Rio Anzú a mass of dark gray limestone resembling the Napo beds and lying at elevations above 4,000 feet suggests an uplift in this area. These beds appear to be nearly horizontal. A sink-hole type of topography has developed on the limestone outcrops. Fossils collected were thrown away by the Indian carriers when they discovered their pack baskets contained rocks. Remnants of red beds capping some of the hills indicate that these limestones are equivalent to those west of Venecia on the Rio Napo.

FAULTING NORTH OF CANELOS

A zone of faulting extends from the headwaters of the Rio Curaray nearly to Canelos, a distance of 30 miles. The best evidence was found in the high ridge between the Rio Curaray and the Rio Villano. The downthrow side is to the east. Beds of lignitic conglomerate are faulted against the red beds. The amount of displacement could not be determined accurately. Some local exposures showed a throw of 150 feet. This fault zone is 25 miles east of the Mirador uplift and may be the eastern escarpment of the high land which extends eastward from the Mirador.

SYNCLINE ALONG THE RIO ARAJUNO

Where the trail from Napo to Canelos crosses the Rio Arajuno there is a syncline in the red beds. It was not followed for any distance, but its position seems to indicate that it follows the course of the Rio Arajuno which flows into the Napo about 10 miles below Venecia. This syncline, with an axis roughly parallel to the Napo anticline, suggests the existence of another anticline southeast of the Napo between that river and the Rio Curaray in an area which was not explored.

EAST OF ALAPICOS

Rock specimens brought from the confluence of the Rio Palora and Rio Pastaza by the Indians resembled the petroliferous limestones at Napo, but the high water in the Rio Palora prevented a visit to those outcrops. They are mentioned as being from a possible uplift similar to that at Napo and Mirador, where the underlying limestones have been exposed by the erosion of the red beds.

EVIDENCE OF PETROLEUM

The Napo limestone is found to be more or less petroliferous. Along the Rio Napo the limestones and black shales are in many places impregnated with asphaltic oil. Small quantities of black oil seep from cavities and bedding planes of the upper Napo limestone east of El Molino de Latas. On the axis of the Napo anticline just west of the settlement of Napo gas escapes from the black shales and can be observed at low water on the north side of the stream. Petroliferous limestones occur in the Mirador uplift and in the area east of Alapicos.

The Hollin sandstone also carries asphaltic material. On the Rio Misahualli near the mouth of the Rio Hollin there are seepages of asphaltic oil from the Hollin sandstone which outcrops on the axis of the Napo anticline. These seepages are from the lower half of the sandstone. The seepage oil occurs with sulphur water and forms pools 10–15 feet across. There is some evidence of natural gas. The upper beds of the Hollin sandstone exposed along the Rio Misahualli are stained with asphaltic oil. East of Archidona the Rio Hollin and its tributary, the Rio Jandachi, cut across the west limb of the Napo anticline and have exposed the Hollin sandstone in their canyon walls. Seepages occur from the oil-saturated sandstone, but the nearly vertical walls have prevented any great accumulation. This oil-bearing sandstone extends for several miles. Its northern limits were not determined.

COMPARISON WITH OTHER AREAS

The oil-bearing beds at Napo may be compared to the Colon shales and limestones of Upper Cretaceous age which occur along the west side of the Maracaibo Basin in Venezuela, 700 miles to the northward. Liddle[1] has measured sections showing a thickness of 3,500 feet of Colon shale overlying 1,000 feet of the upper part of the Lower Cretaceous which lies upon a basal Cretaceous conglomerate. The Colon shales are petroliferous and contain fossils similar to those of the Napo limestone. Along the west side of the Maracaibo Basin several large seepages occur from the upturned Colon beds.

In Colombia Anderson[2] has described the Villeta and Guadalupe beds of Middle to Upper Cretaceous age. Their thickness is similar to that measured on the Venezuelan side of the mountains. In the upper Magdalena Valley Garner[3] has referred to the thick bituminous shales in the Upper Cretaceous as being the probable source of much of the oil found there.

Joseph T. Singewald, Jr., recently announced the results of his observations on the Pongo de Manseriche on the upper course of the Amazon of eastern Peru.[4] He found a thick sandstone overlain by a Cretaceous shale and limestone series, above which are the red beds. This sequence agrees closely with that found in the Napo section, although his thicknesses are considerably greater.

Seepages extending 600 kilometers southward from the Province of Mendoza, Argentina, were found by Robert Anderson[5] to be from beds of

[1] R. A. Liddle, "The Geology of Venezuela and Trinidad" (manuscript for book).

[2] F. M. Anderson, "Original Source of Oil in Colombia," *Bulletin Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 4 (April, 1926).

[3] A. H. Garner, "General Oil Geology of Colombia," *Bulletin Amer. Assoc. Petrol. Geol.*, Vol. 11, No. 2 (February, 1927), p. 153.

[4] J. T. Singewald, Jr., "The Pongo de Manseriche, Peru," paper presented before the Geological Society of America, Madison, Wisconsin, December, 1926.

[5] Robert Anderson, "Observations on the Occurrence and Origin of Petroleum in Argentina and Bolivia," *Bulletin Amer. Assoc. Petrol. Geol.*, Vol. 10, No. 9 (September, 1926), p. 857.

Jurassic and Lower Cretaceous age. They contain many marine fossils and are thought to be the source beds for the seepage oil.

ORIGIN OF THE OIL

The oil found in this area probably has its origin in the Napo limestone, which consists of highly fossiliferous marine limestones and shales of Cretaceous age found to be petroliferous wherever exposed. This oil in the upper beds of the Hollin sandstone may have migrated laterally from the Napo limestone, which is adjacent to it along the flanks of the Napo anticline. Seepages from the base of the Hollin sandstone suggest upward migration from organic beds not exposed.

Igneous intrusions may have played some part in the migration and accumulation of oil in other parts of the region, but in the Napo area, where the best evidences of oil were observed, intrusions have not been found. The oil-bearing rocks are relatively close to the eastern scarp of the Andes and are associated with volcanic flows, but have not suffered any great alteration.

PROSPECTS FOR OIL FIELDS

Geological work has been of a *reconnaissance* nature, all observations being limited to the vicinity of streams or along trails cut through the forest.

The evidence of petroleum found in the rocks of the Napo section leads to the conclusion that the Hollin sandstone has possibilities of production wherever proper depth and structural conditions exist.

Sandstones and shales in the lower part of the red beds may act as reservoirs for oil by migration upward from the uppermost Napo beds. Tertiary beds higher than those observed may also be oil-bearing under structures east of the Napo area.

The Rio Napo oil-bearing Cretaceous beds lying close to the eastern base of the Andes of Ecuador are another link in the chain of oil-bearing Cretaceous strata extending from Venezuela and Colombia to Argentina.

DISCUSSION

JOSEPH T. SINGEWALD, JR.: The Permian area south of Ecuador shows the same stratigraphic units as Ecuador. It differs in absence of volcanics and greater thickness of beds. The Hollin sandstone probably is the same as the coal-bearing quartzitic sandstone of the main Andes, which is lowermost Cretaceous or uppermost Jurassic. The Napo limestone-shale ranges from Albian to Coniacian in age. The red beds in Peru lie conformably on the Napo series, hence must be in part uppermost Cretaceous and may extend into the Tertiary. Overlying the red beds is a younger series of beds of considerable thickness. All of these strata participated in the orogenic movements of the eastern

Andes. In the Amazon Basin are flat-lying beds with a Pliocene brackish-water fauna, long known from collections made by Orton and other early explorers at the town of Pebas. The folding of the eastern Andes occurred probably in Miocene time. The red beds in Peru are sparingly fossiliferous, containing poorly preserved gastropods and a few pelecypods.

EXPLANATION OF PLATES

Plate 9

Figures 1, 2: *Coelopoceras* n. sp. A aff. *C. lesseli* Brüggen and *C. springeri* Hyatt. Side view and cross-section of an internal cast from left bank of Rio Napo, ½ mile above the village of Napo at crest of anticline.

Figures 3–5: *Coelopoceras* n. sp. B from Rio Hollin, 5 miles southeast of Archidona. Figures 3, 4: Side view and cross-section of an internal cast. Figure 5: Side view of another specimen retaining the shell.

All figures reduced one-seventh.

Plate 10

Turonian Fossils from Eastern Ecuador

Figure 1: *Inoceramus labiatus* Schlotheim. Side view of specimen flattened in shale, from Rio Napo, just below village of Napo.

Figures 2, 3: *Roudairia intermedia* Brüggen. Side and front views of specimen from left bank of Rio Napo, 1 mile below village of Napo.

Figures 4–6: *Cyprimeria* n. sp. aff. *C. excavata* Morton, from left bank of Rio Napo, ½ mile below village of Napo. Figures 4, 5: Side and cardinal view of a specimen. Figure 6: Cross-section of hinge of another specimen.

Figure 7: *Inoceramus labiatus* Schlotheim. Side view of specimen flattened in shale from region between Rio Napo and Cordillera Guaçamayos.

Figure 8: *Inoceramus* sp. Side view of specimen from region between Rio Napo and Cordillera Guacamayos.

Figures 9, 10: *Pecten (Neithea) quinquecostatus* Sowerby from region between Rio Napo and Cordillera Guacamayos. Figure 9: View of right valve. Figure 10: View of left valve.

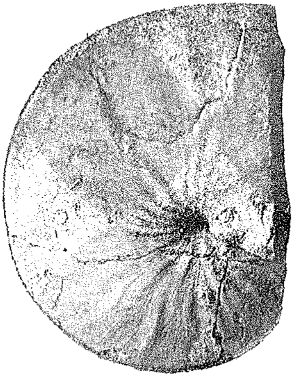
Figure 11: *Exogyra* aff. *E. flabellata* D'Orbigny. Side view of left valve from Rio Jandachi, 3 miles northeast of José Morales' house, which is on Quito-Napo road 4 miles north of Archidona.

Figure 12: *Exogyra* aff. *E. flabellata* D'Orbigny. Side view of left valve from Rio Misahualli between mouth of Rio Tena and mouth of Rio Hollin.

Figure 13: *Arca* n. sp. aff. *A. archiacana* D'Orbigny. Side view of internal cast from locality 1¼ miles east of house of José Morales, on trail leading east to Rio Jandachi. Morales' house is 4 miles north of Archidona on Quito-Napo road.

Figure 14: *Glycimeris* n. sp. Side view of internal cast from same locality as last.

PLATE 9



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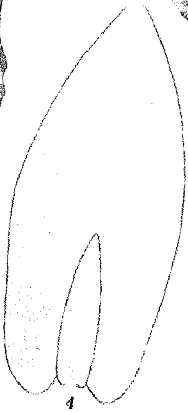

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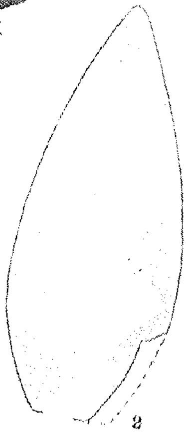

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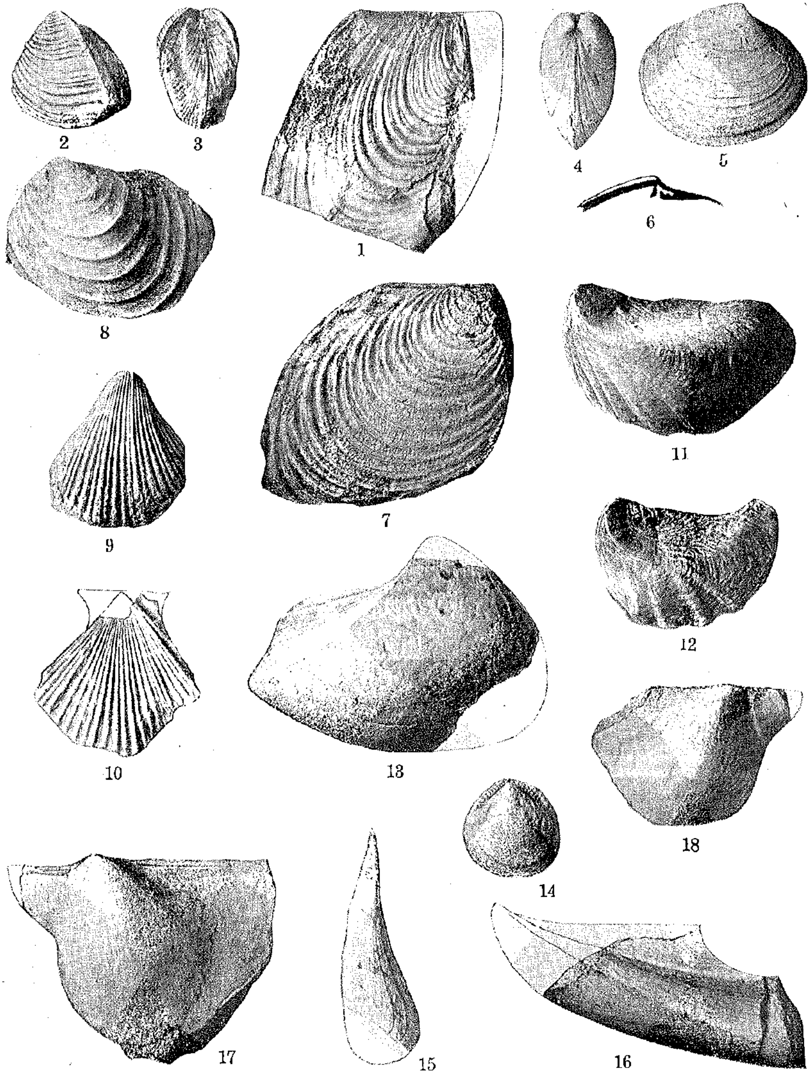
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Figure 15: *Pinna* sp. Side view of internal cast from same locality as last.

Figure 16: *Gervillia* sp. Side view of internal cast from same locality as last.

Figures 17, 18: *Pteria* n. sp. aff. *P. gastrodes* Meek, from same locality as last. Figure 17: Side view of an internal cast of a right valve. Figure 18: Side view of an internal cast of a left valve.

All figures reduced one-seventh.

Plate 11

Turonian Fossils from Eastern Ecuador

All specimens shown on this plate are from locality $1\frac{1}{4}$ miles east of José Morales' house on trail leading east to Rio Jandachi. Morales' house is 4 miles north of Archidona.

Figures 1–3: *Exogyra olisiponensis* Sharpe. Figures 1, 2: Top and side views of natural mold of interior of large (left) valve. Figure 3: View of plaster cast from natural mold of exterior of small (right) valve, somewhat enlarged.

Figure 4: *Exogyra* aff. *E. flabellata* D'Orbigny. Side view of internal cast of left valve.

Figures 5, 6: *Trigonia crenulata* var. *peruana* Paulcke. Side and cardinal views of internal cast.

Figure 7: *Trigonia* aff. *T. hondaana* Lea. Side view of internal cast.

Figure 8: *Pecten* (*Neithea*) *aequicostatus* Lamarck. Side view of internal cast.

Figure 9: *Pecten* (*Syncyclonema*) n. sp. Side view of internal cast of part of valve.

Figure 10: *Plicatula* aff. *P. auressensis* Coquand. View of squeeze from mold of surface of part of valve.

Figures 11, 12: *Modiola* aff. *M. socorrina* D'Orbigny. Figure 12: View of squeeze from mold of exterior of left valve. Figure 11: View of internal cast of right valve.

Figure 13: *Modiola* n. sp. aff. *M. flichei* Peron. Side view of internal cast.

Figures 14, 15: *Liopistha* n. sp. aff. *L. ligeriensis* D'Orbigny. Side and cardinal views of internal cast of nearly complete shell.

Figures 16, 17: *Cardita* n. sp. aff. *C subparallela* Gerhardt. Side and front views of internal cast.

Figure 18: *Protocardia appressa* Gabb. Side view of internal cast.

Figures 19, 20: *Venus* n. sp. Figure 19: Side view of internal cast of right valve. Figure 20: View (× 4) of squeeze of hinge.

Figure 21: *Tellina?* sp. indeterminable. Side view of internal cast.

All figures except figure 20 reduced one-seventh.

Plate 12

Turonian and Albian Fossils from Eastern Ecuador

Turonian Fossils

Figure 1: *Mactra?* n. sp. Side view of internal cast from locality $1\frac{1}{4}$ miles east of José Morales' house, on trail leading east to Rio Jandachi. Morales' house is 4 miles north of Archidona.

Figures 2, 3: *Corbula* aff. C. *peruana* Gabb. Side and cardinal views of an internal cast from same locality as last.

Figures 4, 5: *Gyrodes* n. sp. aff. *G. depressa* Meek. Two views of an internal cast from same locality as last.

Figure 6: *Turritella* aff. *T. vibrayeana* D'Orbigny. View (×2) of fragment from same locality as last.

Figure 7: *Aporrhais* aff. *A. costae* Choffat. View of internal cast from same locality as last.

Figure 8: *"Fusus"* n. sp. aff. *F. ubaquensis* Gerhardt. View of an internal cast from same locality as last.

Figures 9–11: *Mammites* n. sp. (=*Mortoniceras cañaense* Gerhardt?). Same locality as last. Figures 9, 10: Side and back view of internal cast. Figure 11: View of plaster cast from mold of exterior of same specimen.

Albian Fossils

Figures 12, 13: *Inoceramus concentricus* Parkinson. Side and front views of an internal cast from Rio Hollin, 5 miles southeast of Archidona.

Figure 14: *Plicatula* aff. *P. gurgitis* Pictet and Roux. View of an internal cast from same locality as last.

Figures 15–17: *Brancoceras* n. sp. From same locality as last. Figures 16, 17: Side and siphonal views of internal cast. Figure 15: Suture of another specimen.

Figures 18–20: *Oxytropidoceras* (*Manuaniceras?*) *carbonarium* (Gabb) (=*Schloenbachia acutocarinata* Shumard of many authors). Side and siphonal views and suture (×2) of specimen from same locality as last.

All figures except figures 6 and 18 reduced one-seventh.

Plate 13

Albian Fossils from Eastern Ecuador

Figures 1, 2: *Oxytropidoceras* n. sp. aff. *O. belknapi* (Marcou). Side view and cross-section of only specimen, an internal cast retaining fragments of the shell, from Rio Hollin, 5 miles southeast of Archidona.

Probably Albian Fossils

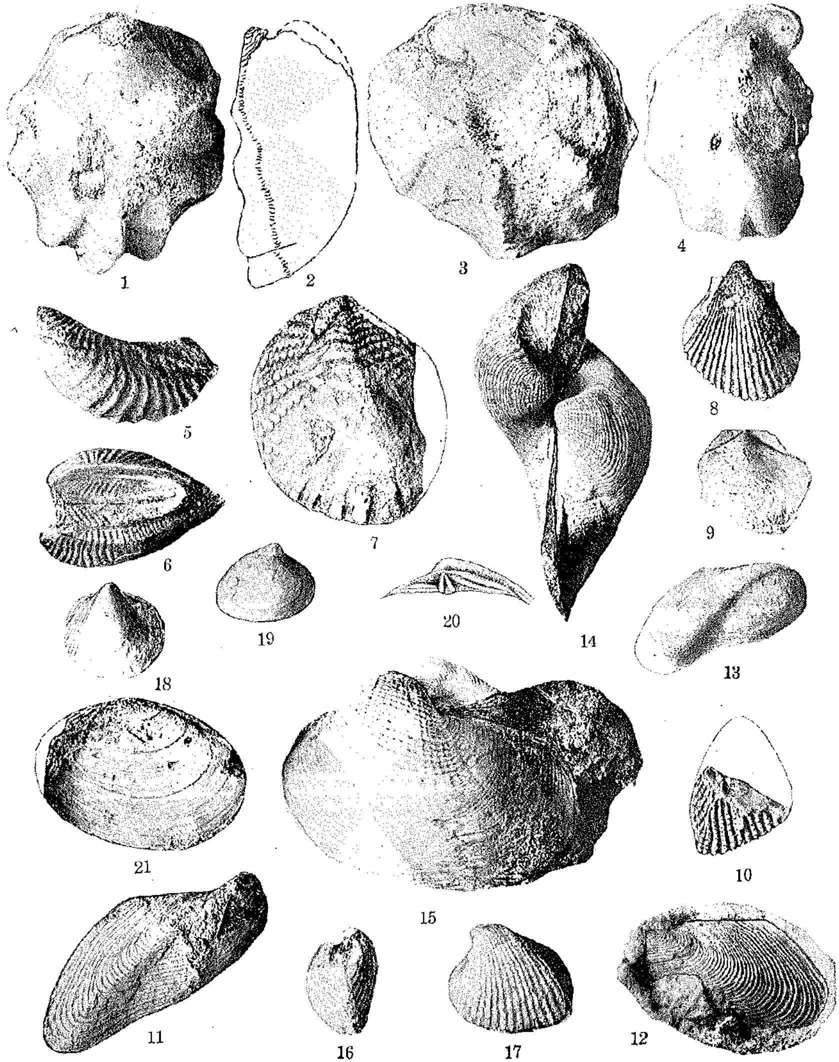
Figures 3, 4: *Exogyra* aff. E. *africana* Coquand. Side and front views of an internal cast from Ursuyacu at crossing of Quito-Napo road, about 9½ miles north of Archidona.

Figure 5: *Pecten* (*Neithea*) n. sp. aff. *P. phaseola* Lamarck. View of only specimen, from same locality as last.

Figure 6: *Pecten* n. sp. aff. *P. marrotianus* D'Orbigny. View of only specimen, from same locality as last.

Figures 7, 8: *Lima* n. sp. View of only specimen and part of surface (×4) from same locality as last.

Figure 9: *Plicatula* aff. *P. gurgitis* Pictet and Roux. View of a specimen from same locality as last.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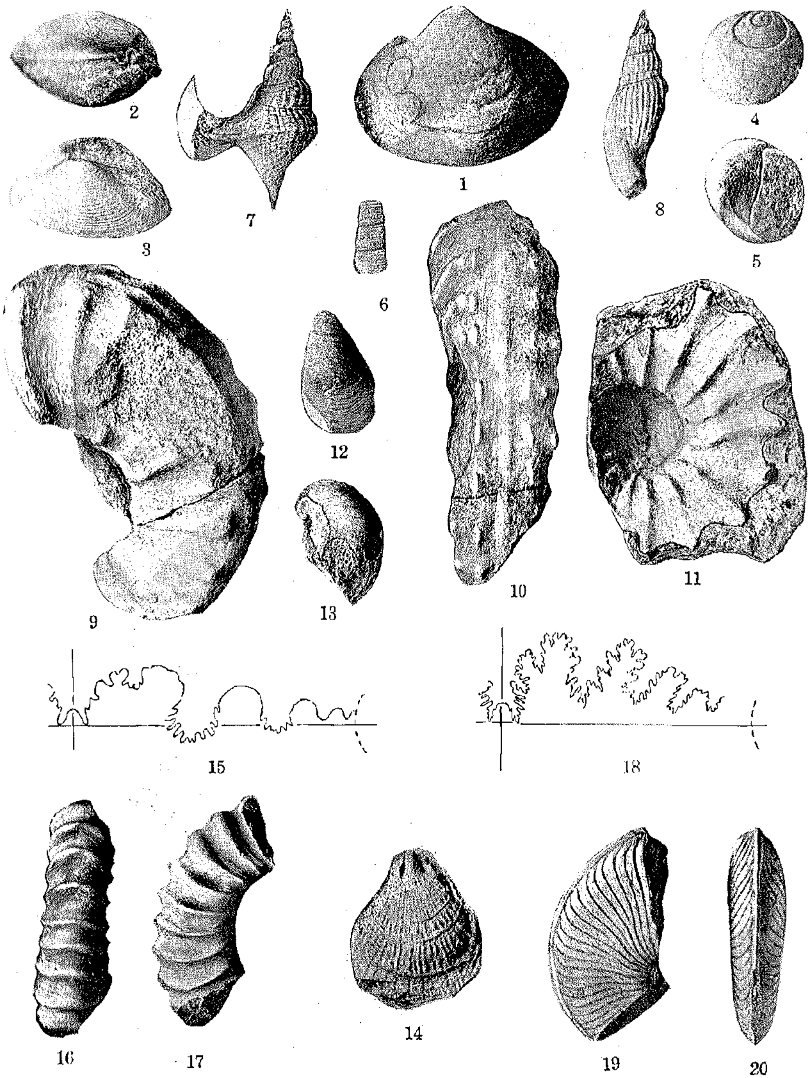
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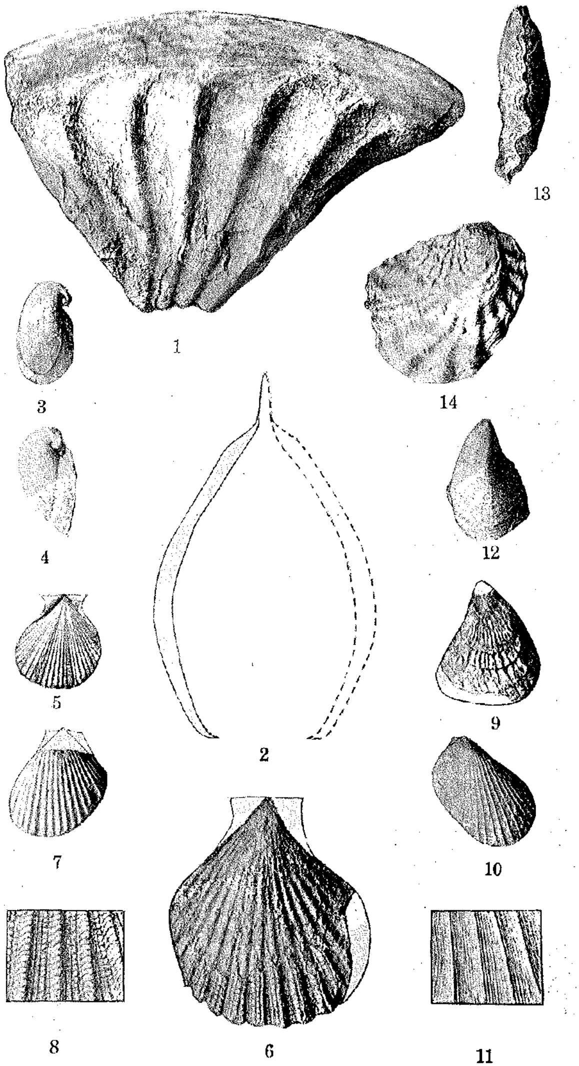
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Figures 10, 11: *Lima* n. sp. aff. *L. intermedia* D'Orbigny. View of only specimen and part of surface (×4) from region between Rio Napo and Cordillera Guacamayos.

Figure 12: *Inoceramus concentricus* Parkinson. Side view of an internal cast from region between Rio Napo and Cordillera Guacamayos.

Figures 13, 14: *Ostrea syphax* Coquand. Side and front views of specimen from region between Rio Napo and Cordillera Guacamayos.

All figures except figures 8 and 11 reduced one-seventh.