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DEVELOPMENT OF THE VOLCANO COTOPAXI IN ECUADOR

V. Lysenko: *Development of the Volcano Cotopaxi in Ecuador.* — Sborník ČSGS 85:3:966—178. — In this paper the author describes the results of the Czechoslovak volcanological expedition to Ecuador in 1972 in which he himself took part as a geologist. Observations on the Cotopaxi were made by two separate groups: the geological group, interested in the petrography and the chemism of the five stages in which the volcano had been built up, and the geomorphological group studying the changes in the development of the relief of the volcano.

Introduction

The volcanological expedition was sent out by the Czechoslovak Ministry of Culture in the year 1972 to work in Ecuador. The Central Geological Institute and the Czech Geological Board took part in professional preparations. During the tree months' stay the geological part of expedition have executed:

1. The detailed geological and geomorphological exploration of the volcano Cotopaxi resulting in arrangement of the original geological and geomorphological map of the Cotopaxi area (cca 250 sq.km) in the scale 1:50 000. As a part of the exploratory work there was the execution of two climbs on to the volcano summit and the first descent to the crater bottom.

2. The comparative collection of rocks from the further localities connected with climbs of the Rumiñahui shield (4 712 m), Chimborazo (6 297 m) and the very difficultly accessible volcano Sangay (5 437 m), the most active South-American volcano.

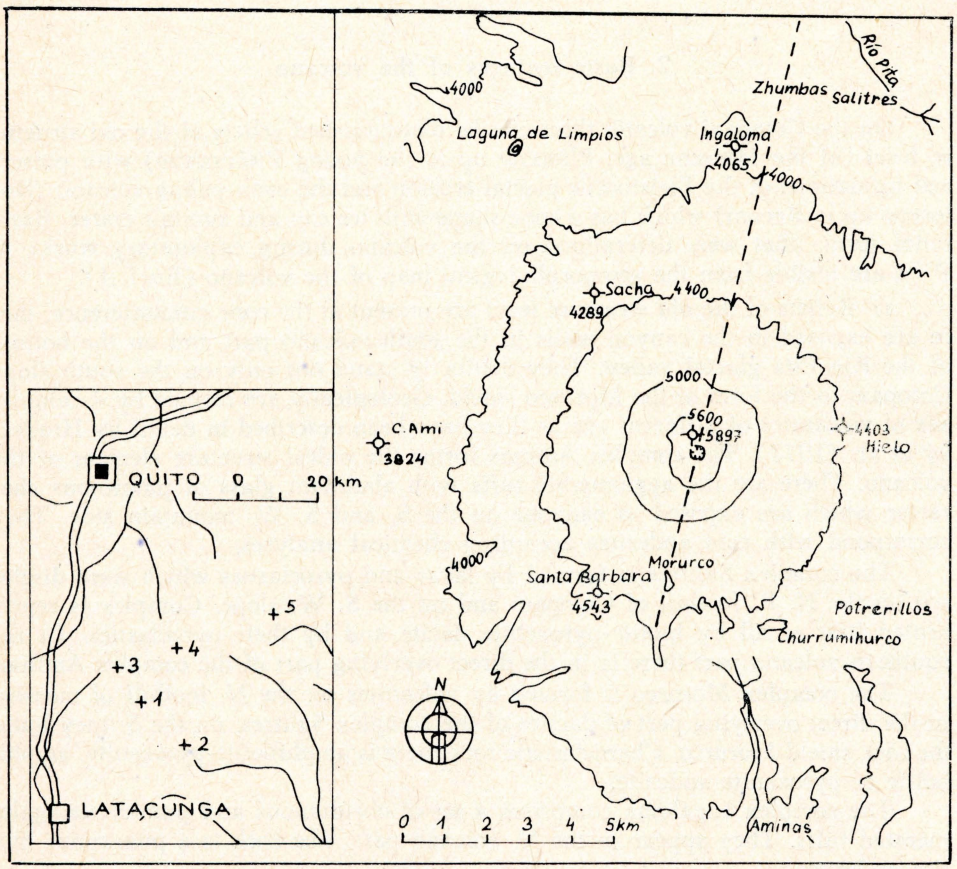
The summarized evaluation of exploration results in the form of a report with map documentation of Cotopaxi forms a part of basic materials for proclamation of the National Park Cotopaxi which is in preparation.

Exploration of the volcano Cotpaxi in the year 1972 was carried out in cooperation of two working groups: geological, which was concentrated on the petrography and chemism of volcano structure levels and the geomorphological one, which has studied the volcano relief development and the near surroundings in the dependence on the origin of volcano levels and on the climatic deviations in the Pleistocene. The presented paper is a summary of results obtained by the geomorphological group which has worked in field in the following basic composition: G. Ginzel, prom. geol. M. Krůta and prom. geol. V. Lysenko (the group leader).

1. History and research review

Volcano Cotopaxi is situated in the west part of the east mountain band of Andes called Cordillera Real (Cordillera Oriental). The exact volcano position is 0°38′S. latitude and 78°26′W. longitude, 50 km to the south from the Ecuador capital Quito and 35 km to the north-east from the town Latacunga (Fig. 1).

The volcano altitude reaches 5 897 m. It belongs to the most highest active volcanoes in the world. Cotopaxi is a typical stratovulcano with historically verified periods of the increased activity. Volcano eruptions has mostly volcanic character, stadia of inactivity are irregular and commonly considerably long. The main periods of higher activity appeared in the years 1532—1534, 1742—1768, 1803, 1844—1886 and 1903—1904. The strongest eruption recorded in June 1877 has caused the extinguishment of the settlements Mulalo and Latacunga by the destructive mudd flows. The eruptive cloud has reached the altitude of 8 000 m. The extremely fine dust was wind-blown as far as to the port Guayaquil on the



1. Situation of the volcano and the locality described in the paper. Volcano Cotopaxi (1), Quilindaña (2), Rumiñahui (3), Sincholagua (4), Antisana (5), Dash line — course of the sectional view Fig. 6.

Pacific Ocean, the steamer Islay has registered dust-fall in the distance of 334 km from the coast. The last lava effusion was observed in the year 1942. The contemporary activity is limited on exhalations from the crater walls (the last increased exhalations were registered in the year 1975).

The first vulcano illustration came to Europe shortly after the Spanish had conquered Inca Empire. Only in the year 1872 the German geologist A. Reiss and the Columbian Escobare have succeeded in reaching the volcano summit. By the research of volcano there were engaged especially German investigators: von Humboldt (1838), Reiss (1873), Stübel (1897), T. Wolff (1892) and Mayer (1907). F. von Wolff (1929) has summarized and discussed all the information from the research works dealing with Cotopaxi and further volcanos of the South America. In detail there is described volcanism of Cotopaxi in an aggregative paper on Ecuador geology by Sauer (1971). The complete results of the Cotopaxi Epedition 1972 are summarized in the Spanish copy of the final report elaborated for the Czech Geological Board (1973). Hall (1977) presents the up-to-date knowledge about the description and gives his opinion on the degree of investigation of the Ecuador volcanoes.

2. Basic features of the volcano

On the Cotopaxi volcano there can be distinguished relicts of the old structure level (of the Miocene age, Pliocene up to the young Pleistocene) with preserved formations of the Pleistocene glacial erosion and the even young volcano (Holocene up to Recent) which has a cone shape with ice cap and summit crater. Basic relief forms that were determined on the volcano during exploratory works in 1972 are visible from the geomorphological map of the volcano (Encl. 1).

a) Relicts of the old structure level are present at the cone circumference, there are exposed in the canyon walls in the south volcano part and on the bottom of the Rio Pita glacial valley. They distinctly stand out only on the south slope Cotopaxi in the form of the Morurco shield. Geologically are formed by 4 complexes of volcanites of different age as they have been described in detail by Hradecký et al. (1977). The complex Aminas forms the oldest structure element of the volcano. There are the agglomerate tuffs with abundant glass of pumiceous character which are exposed in canyons on the S. and S. W. mountain side. They correspond with acid andesites according chemical analyses.

The complex Salitres is formed by lavas and pyroclastics which were disclosed on the N. E. foothill of Cotopaxi and on the S. W. slope. Complex is represented first of all by biotite-pyroxenite dacite and by their pyroclastics. In the southern volcano part there is in the direct overlying part of the complex Aminas.

The complex Morurco is formed by volcanites on the N. foothill of massive in the direct overlying part of dacites of the complex Salitres, on the S. they build the rock shield Morurco. Characteristic rock there is amphibolite-pyroxenite, amphibolite or pyroxenite andesite.

The complex Ingaloma comprises a set of obsidianous and pumiceous agglomerated tuffs. They appear in the N. volcano part. The rock is a pumiceous biotite andesite.

Occurrences of the oldest complexes in the Cotopaxi area don't exceed 4 500 m of altitude (Aminas and Saliteres). They are products of a low-plain volcano with the center cca 4 km to the S.S.W. from the active center of the contemporary

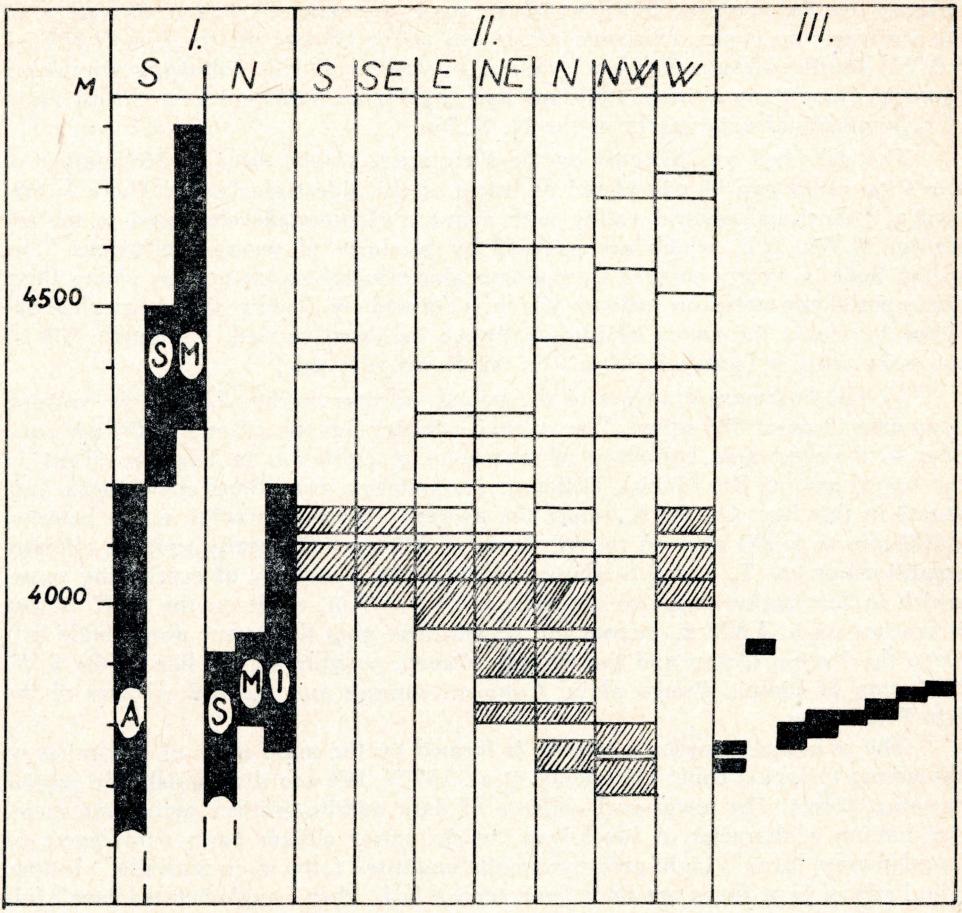
volcano. In the complex Salitres, where some nunataks remember on relicts of the squeezed up cones, existence of several active centers on the line N.N.E.—S.S.W. (Salitres-Santa Barbara) cannot be excluded. The following complexes Morurco (maximum altitude 4 800 m) and Ingaloma (4 200 m) have the direction of a longitudinal axis nearly of the N. S. line.

The old level was affected by the Pleistocene glacial erosion. Modelation of Rio Pita valley can be considered as traces of the oldest glaciation. There is formed a wide trough-shaped valley with a group of nunataks elongated to the direction N.W.—S.E. which are covered by products of younger effusions. The valley floor is mostly covered by younger glaciofluvial sediments, on places there are exposed the striae on bedrock which is formed by dacites of the complex Salitres. Similarly the valley of Limpio Pungo has been formed. Its bottom lies at the same altitude (today 3 700 m) on the N. volcano side.

b) The basement diameter of the young vulcano reaches 22 km, the volcano body area is about 380 sq.km. The volcano territory lies in „páramo" climatic zone near to the west area boundary of maximum precipitation in Ecuador (Tena in the upper part of Rio Napo). Different precipitation conditions on Cotopaxi originate in this fact. On the E. slopes the average year precipitation varies between 2 000 mm to 2 500 mm, on the W. round 1 500 mm. Generally rougher climatic conditions on the E. and S.E. slopes influence the boundary of everlasting snow, which in this region drops to the altitude of 4 500 m, while on the N.W. slopes it reaches up to 4 800 m. Across the region there goes the recent waterdivide between the Pacific Ocean and the Atlantic Ocean, roughly on the line of the S.W. limitation of Limpio Pungo plain, Cotopaxi summit and the S.E. closure of the Rio Pita valley.

The so called complex Cotopaxi is formed by the main mass of volcanites of the young Cotopaxi cone. (Hradecký et al. 1977). We can distinguish five partial structure levels. The lower part consists of dark middle grained pyroxenite andesite having a character of block-lava, in the lower stream parts with layers of „agglomerate lavas". Light grey pyroxenite andesites („the main andesite") follow. The basis of lava flows are built from tephra beds, then „agglomerated lava" follows with abundant boulders of coarse grained tephra. The cyclus is completed by a large flow of block-lava. This sequence is repeated on the E. slopes up to five-times. Grea-red autoclastic lava having composition of pyroxenite andesite are present as the overlying rock. On the W. slopes the autoclastic lavas are covered by dark grey block-lavas consisting of pyroxenite andesite. As the youngest effusive rock of the Cotopaxi complex there are black sluggy aa-lavas consisting of pyroxenite andesite or olivinite-pyroxenite andesite respectively, on places with transition to basalts.

In morphology of young cone there expressively took parts effusions of the „main andesite" of the Cotopaxi complex. Stratification to step-shaped, gently dipping plains is typical for these effusions. (Fig. 2). In slope trenches (barrancos) the lava flows form from the altitude 4 000 m up to 4 700 m conspicuous steps predominantly exposed by retrogressive erosion. Concentration of the plain relief to the northern part of Cotopaxi prove the prevalance of block lava effusions in the N.E. and expecially in the N. volcano areas. On plains there often appear local closed very shallow waterlogged basins also with lakes, with well developed vegetatonal cover (turf superficial layer formed by several grass kinds). Hummocky soil relief (thufury) is characteristic. The width of thufurs varies from 0,5 to 0,8 m.



2. Height levels of complexes of the old volcanic level (I.), lava platforms and steps (II.) of the Cotopaxi complex and nunataks in the Rio Pita valley (III.).
A — Aminas, S — Salitres, M — Morurco, I — Ingaloma (Lysenko 1979).

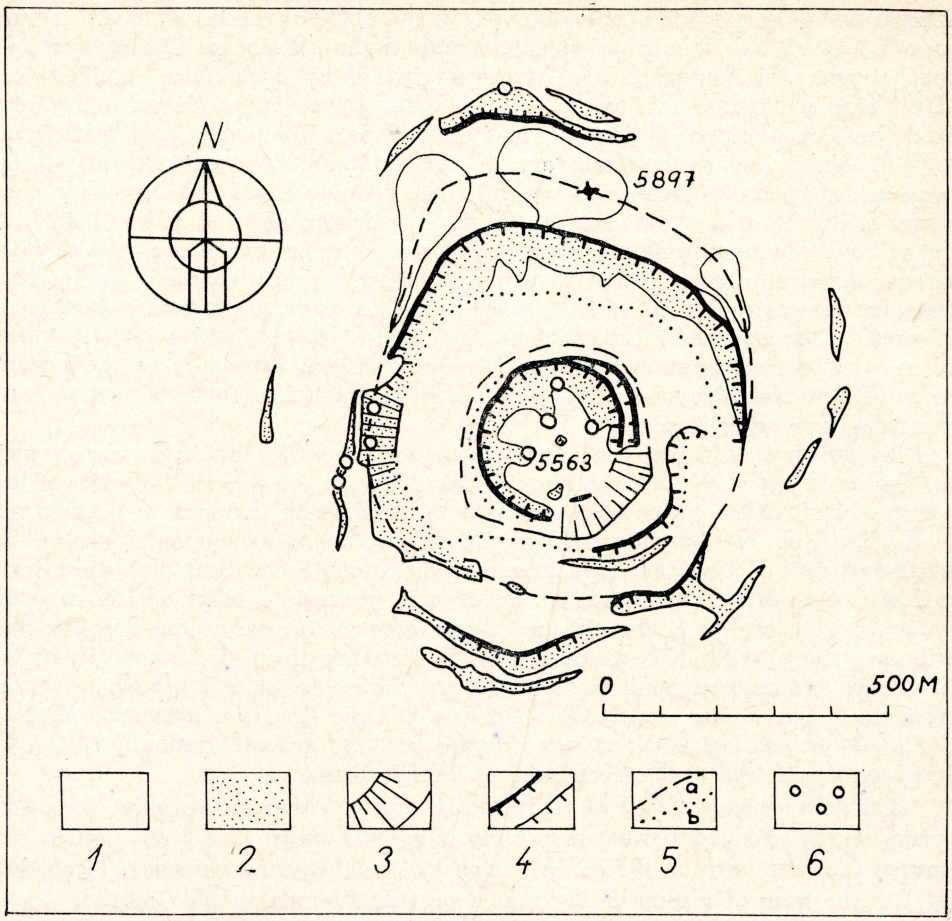
The ice cap is represented by a firn glacier. Its collecting area is formed by the whole surface of slopes on its summit part, which is concave. In the area of the boundary of overlasting snow short glacier tongues decline from the ice cap. In the front part of tongues stratification is perceivable, the underlying moraine is often exposed in the lower part. The forehead parts of tongues are in this time on regression. In the postglacial period glacier tongues extended lower about of 500 to 700 m distance than in the time being. As a consequence of their regression there remained in the altitude over 4 300 m exposed short shallow hanging glacial valleys with the evident glacial modelation: glacial slickensides, roches mounton nées (in the N.E. part). As typical there are cirque valley head respectively cirques on the W. and N.W. slopes in the altitude of 4 600—4 700 m. In the northern part in the altitude of about 5 700 m the monotonous glacier cap surface is interrupted by a rock failure.

Volcano slopes decline (on the S.W. and W.) down into the interandian

depression to the altitude about 3 000 m. In the other directions Cotopaxi is surrounded by the neighbouring vulcanoes Rumiñahui, Pasocha, Quilindaña and Sincholagua. The contact area of slopes is covered by thick fluvial and glaciol--lacustrine sediments, the foothill of Cotopaxi slopes is in the altitude over 3 500 m. Dip of slopes is 15—20° in the lower part, in the top part reaches up to 40°. Slopes below the boundary of everlasting snow are furrowed up by slickenside trenches (barrancos) which in the altitude about 4 000 m have character of deep V-shaped ravines. On the S. they deepen down to 200 m below level of the contemporary slopes. In foothill parts of slopes barrancos have shallow bottom in which the up-to-date glacier waters erode a new channel. Ridges between barrancos are formed by older generation lava flows mechanically weathered, covered by the soliflued most youngest tephras. In the cohesionless material there often come in consideration slides, which are observable especially on the eastern slope of Cotopaxi. Barrancos have acted often as ways for effusions of the youngest lavas and mudflows.

In the time of young cone creating changes in valley net and river divides took place in the N.W. volcano part in river basin of the Rio Pita. Relicts of the valley of N.S. direction by which the area to the E. from Ingaloma is drained off to the Rio Pita, can be considered as the oldest. Relicts valleys on slopes in the north-east part of Cotopaxi have preserved directions E.S.E. and they were drained off to the Rio Tamboyacu. As an example there is a relict of 100 m wide valley on the locality Hielo. By the reverse erosion in case of the Rio Pita the tributary rivers in the N.E. volcano part the breaking down of the majority of N S. valleys had occurred and creation of a new valley net of N.E.—S.W. direction took place. The divide between the Rio Pita and the Rio Tamboyacu has displaced to the S.too. The north-eastern volcano part drained off originally to the S. has been transferred to the river basin of the Rio Pita.

On volcano slopes, first of all in the N. and N.W. region selective corrosion occurs on the uncovered strata in profiles of canyon walls. Blown out sand is deposited predominantly at the opposite slopes of neighbouring volcanoes (Rumiñahui) in the form of a dune or it forms elongated mounds on the Cotopaxi slopes and accumulates as dunes on the leeward side of barrancos. As a significant factor in modelation of young cone there are volcanic mud flows — lahars which are called avenidas on the South-American continent. In the eruptive activity period of volcano the melting of top glacier takes place in consequence of which mud flows originate. The contemporary deposition of lahar material with the eruptive one is proved by alternation of washed material strata with pyroclastics in profiles of the youngest accumulations in the region of Limpio Pungo — Campamento Mariscal Sucre. Lahar material is formed by pyroclastics of varied size, ash, boulders, old lavas and waterworn moraines. Lahar material accumulates in the lower parts of slope streams, at foothill on plains and it fills plain valleys with the original glacial modelation. In parts of retarding flow it is gravitationally classified. In the N. and N. W. volcano part lahar accumulations accompanied by pyroclastics have caused a sink of slope streams by their covering. Outflows are present in that parts where the lowered terraine surface crosscuts the gradient curve of the covered stream. On four localities in the N. Cotopaxi part we can observe the development of pseudokarst relief respectively the origin of pseudokarst phenomena (swallow holes, dolines, outflows, sink holes, spring caves etc.), described in the papers of Lysenko (1975, 1976).



3. Situation of the Cotopaxi crater (Lysenko 1973).
1 — ice, 2 — volcanites, 3 — slight slopes, 3 — sheer up to vertical walls, 5 — a-axes of elevations, b-axes of depression, 6 — fumaroles (solphatare exhalations).

Crater Cotopaxi (Fig. 3) has 800 m in diameter. Depth of the whole crater is 334 m from the top, from the marginal rampart on the W. reaches 226 m. It is a double crater having external somma and inner crater. Depth of the external part is 212 m from the top, from the W. marginal rampart 104 m. Depth of the inner crater is 122 m. The inner crater has about 250 m in diameter. Crater walls are vertical up to overhanging (ice covered walls). Crater glaciation is wholy the largest on the N. and E. crater side. On the foothill of the N. wall and on the W. crater side there have been solfataras with H_2O, H_2S and SO_2 in action in the year 1972. On the 2nd of September 1972 temperature of solfataras was 80°C. At that time a thin column of water vapours and CO_2 with temperature of 10°C ascended from the shallow volcanic funnel in the crater middle. On the somma slopes gases with prevailing content of H_2O vapours of 40°C temperature exhalated at the beginning of August 1972. In September there were no exhalations and rock outcrops were covered by snow.

3. Development of the volcano Cotopaxi

Volcanites are dominant components of Sierra. On the N. of Ecuador they cross to Columbia, on the S. they are interrupted by intrusives and sediments of Cretaceous Period, volcanoes appear as far as in the S. Peru. The main volcanic phase in Andes began at the end of Tertiary (Pliocene) as the accompanying activity of the so called Ketschuan folding. As acctive there appear systhems of parallel faults first of all of the N.N.E.—S.S.W. directions which determine direction of the whole range and the main weakened zone of the N.-S. direction which forms the boundary of Andes. As for Cotopaxi concernes there are the lines as follows: Cotopaxi, Sincholagua, Puntas and Cayambe (cca 25°) and Altar, Tungurahua, Cotopaxi (N.—S.). Change in volcanites chemism is a characteristic development sign of this young phase of volcanism in Ecuador. Basicity of effusives and pyroclastics increases generally from rhyolites or trachytes of Miocene over dacite of Pliocene, amphybolite or pyroxenite andesite of Pleistocene up to Recent basic pyroxenite andesite which sometimes pass up to olivinic basalte (Hradecký et al. 1977). The scheme has many deviations which are caused by local development and by the entire shifting of active zone from the W. to the E. Thus zones of different activity degree exist side by side. Cordillera Occidental and the W. Cordillery Real part are characteristic by volcanism with fading activity, fully active there are volcanoes of the E. part of Cordillery Real and Fila Oriental. From the 35 described Ecuador volcanoes there are active (Hall 1977) Guagua Pichincha — 4 794 m, Quilotoa — 3 914 m (Cordillera Occidental), Antisana — 5 705 m, Cotopaxi — 5 897 m, Tungurahua 5 016 m and Sangay — 5 430 m (Cordillera Real), Reventador — 3 485 m, Sumaco — 3 828 m (Fila Oriental). Sangay and Reventador are the most active volcanoes of Ecuador and South America. They belong also to the youngest volcanoes, they are of postglacial age and in the time being they produce andesite and basalte lavas and pyroclastics.

On the volcano Cotopaxi there are preserved all the structural levels in comparison with the other Ecuador volcanoes. The scheme of the volcano development is presented on the Tab. 1. Complex Aminas, Salitres, Morurco and Ingaloma form the old volcanic level (Miocene — Younger Pliocene), complex Cotopaxi represents the basic structural element of the young cone (Holocene — Recent).

The erlier authors consider the even shield Morurco together with some other rock formations of Salitre and C. Ami to be relicts (caldera) of an old volcanic cone (Sauer 1971), which has been flung to all parts by the final sizeable explosion. In this case the inner caldera part should have cca 11 km in diameter. This theory seems to be little probable. On the one hand origin of caldera by an axplosion and by ejection of the top cone belong to the very rare phenomena on the other hand all the yardage of volcanic ejecta in the near surroundings should scarcely be sufficient for filling of caldera of the above mentioned diameter. It can be also presumed that all the top volcano part of old level had fallen to the depth but more likely the old volcanic level has the active centrum accentrically situated regarding the recent volcano i. e. about 3—4 km to the S., respektively S.S.W. from crater of the contemporary Cotopaxi. This hypothesis is supported by fact that several times higher thickness of old level volcanites exists in the southern part in comparison with the northern one, the difference of 1 000 m in altitude between complexes on the S. and on the N. and finally also the fact that only conspicuous relict of the old level, which is present in the area Cotopaxi — the rock shield Morurco — corresponds by height with other volcanic relicts of the Pleistocenne: Rumiñahui 4 712 m, Quilindaña 4 750 m, Sincholagua 4 880

Tab. 1. Schema of the volcano Cotopaxi development

Stratigraphical classification		Main series of volcanites		Basic features of volcano relief development
QUATERNARY	Recent	Cotopaxi complex	aa — lavas	— slope destructions by climatomorphological processes, retrogressive erosion of lava steps in canyons (barrancos) — historical lava effusions — shifting of the everlasting snow boundary to altitude 4 700 m (younger lahar phase) — closure of the effusively-explosive activity — development of canyons and pseudokarst phenomena — limitation of glaciation on the top part — ice cap (about 500—700 m lower than today) — block lava effusions — origin of step platforms — regeneration of volcanic activity, effusively-expolsive volcano activity
	Subrecent		block lavas autoclastic lavas	
	Holocene		block lavas „main andesites"	
	Young Pleistocene	individual eruptions, effusions relatively quiet period		— glaciofluvial and river erosion, erosion levels (Zhumbas) — redoposition of pyroclastics (older lahar phase) — regression of glacier — 4th glaciation stage, the everlasting snow boundary under 3 000 m of altitude — low thick valley glacier in the Rio Pita — Andes ascension in the whole
	Middle Pleistocene	old volcanic level	Ingaloma complex	— final activity of the old level, periclinal sheets of pyroclastics
				— 3rd glaciation stage, he largest glacial erosion (Morurco, Zhumbas, Salitres), enlargement of glacial valleys — Andes ascension in the whole
			Morurco complex	— effusive activity of the lower Cotopaxi level — rock shield Morurco origin, covering of complex Salitres by pyroclastics
	Old Pleistocene			— 2nd glaciation stage of shield character, origin of glacial valleys Limpio Pungo and Rio Pita, glacial erosion in the area of Salitres, Zhumbas and Aminas. — 1st glaciation stage — inexpressive in Andes — weakening of volcanic activity — overwashing of Tertiary volcanic materials
TERTIARY	Pliocene		Salitres complex	— main phase of Pliocene volcanism as an accompanying phase of Ketschuan phase of orogenesis
	Miocene		Aminas complex	— complex of pyroclastics on the S. and S.W. volcano side

m. From the petrographical point of view andesites Morurca correspond with lava of the volcano Quilindaña, further comparisons have not been executed.

Glacial erosion was an integral part of old volcano development in Pleistocene. Absence of moraines makes difficult to performe a reconstruction of the older glaciation. Partly they were buried by younger pyroclastics, in part there were incorporated into the following lahars in which the morainic material could hardly be found out as the even lahar material due to its bad performance and unclassified character remember on moraine layers (Meyer 1907).

The main glacial erosion falls into the 2^{dn} and 3rd glaciation stage of Andes in old and middle Pleistocene (Tab. 1.). Rio Pita trough valley and similarly formed valley of Limpio Pungo were created by the action of valley glaciers which fused in the region of the present elevation point Ingaloma where the original relief is completely covered by products of younger effusions. Probably low thick little movable glacier tongues have come in consideration, they were fed partly by its own firn cover partly by the ice caps of Cotopaxi and Sincholagua. The connection of a tongue from the direction of the volcano Sincholagua is confirmed by turning of a relatively great nunatak (length 80 m, height 30 m) to the direction N.E.—S.W. to the mouth of a distinct valley on the slope of this volcano. Rock relief of the complex Salitres modeled by ice is covered on some places by pyroclastics of the Morurco complex.

Glaciation is consequently older than the complex Morurco which is usually classed with volcanic phase of the middle Pleistocene (Hradecký et al. 1977) and coincides with the 2nd glaciation stage of Andes in the old Pleistocene.

Before further glaciation the Rio Pita valley was probably filled by partly washed pyroclastics of the Morurco complex. Their relicts can be found on both the valley banks. The 3rd glaciation stage has caused the extension of the contemporary glacial valleys and has caused the first large glacial erosion of young volcanoes (of the rocky Morurco shield).

The last glaciation follows after a great tuff-obsidiane volcanic phase which had caused rather complete covering of the original relief by pyroclastics. They can be found individually on the right side of the Rio Pita valley where they were deposited as glaciofluvial accumulations (Zhumbas area). Erosion intensity of glaciofluvial and fluvial flows increases at the end of glaciation contemporary with the intensifying of volcanic activity. Glaciation is bound to the Cotopaxi top part-ice cap.

Large effusions predominantly of block lavas represent the complex of Cotopaxi young volcano. In volcanic cone morphology they are present as step shaped slightly inclined plains in the foothill slope parts and as steps in barrancos. Effusions prevail in the N. E. and especially in the N. volcano area. Effusions follow the original plain relief of the old volcanic level. From the extend area of main effusions of the Cotopaxi complex there is evident their eccentricity in comparison with the contemporary volcano axis. Effusions of the lower parts of Cotopaxi complex have the predominant direction to the N., „main andesites" to the N. up to the N.E., autoclastic lavas to the N., N.W. up to the W. the following young block lavas to the N. up to the S.W. and S. Cover of pyroclastics (agglomerates and tuffites) is irregular and it obliterates partially the block lava plain relief.

In the dependence on a group of physical-geographical factors with prevailing climatic elements there takes place the shift of ice cap of about 500—700 m to higher altitude on the young volcanic cone, the destruction of slopes furrowed up by radial furrows. By a strong retrogressive erosion in the gathering zone of the

Rio Pita the waterdivide between Rio Pita and Rio Tamboyacu was shifted to the S. Lahars are important factor in the period of eruptive activity. The development of young recent volcano has caused covering of the old volcanic level.

Conclusion

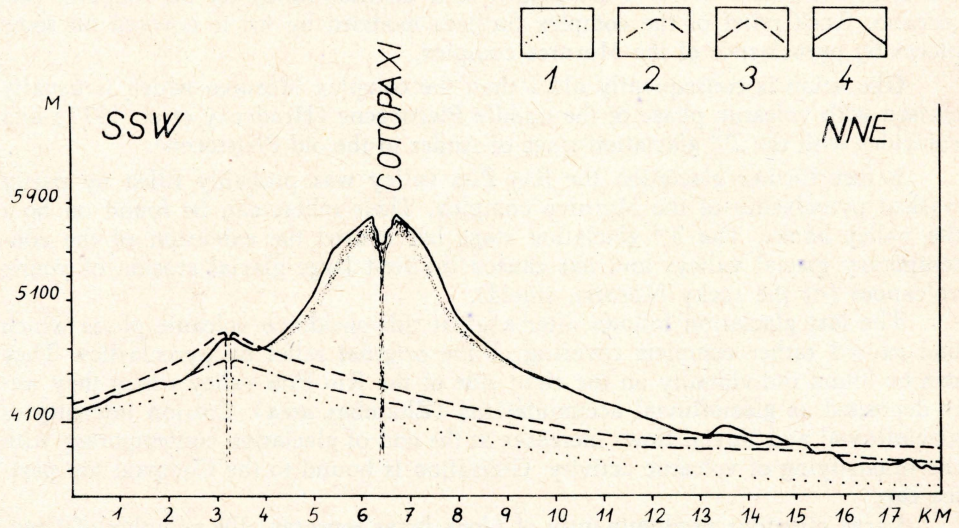
Basic features of the volcano Cotopaxi development are conditioned by:

a) geological development of Andes as an old mobile zone with parallel fault systhems from which the line N.—S. and N.N.E.—S.S.W. (25°) seems to be fundamental for Cotopaxi.

b) development of the volcano levels which differ in age, petrographic composition and chemism of the young volcanic phase in the Ecuador Andes.

c) glacial erosion of the old volcanic level in Pleistocene.

d) in the youngest development phase, (Holocene up to Recent) besides the volcano activity, the relief development i dependent on a group of physical-geographical factors with prevailing climatic elements.



4. Section through the volcano Cotopaxi; 2,5 — times overelevated (V. Lysenko 1979); 1—3 — levels of the old volcanic level (Complexes Aminas, Salitres, Morurco), 4 — young volcano relief

As a result there is the contemporary recently active stratovulcano typically developed which is formed by:

a) relicts of the old volcanic level on the boundary of recent volcano with preserved structural levels from Miocene, Pliocene up to young Pleistocene,

b) relicts of glacial erosion in Pleistocene accumulated to the area of Limpio Pungo and Rio Pita valleys which is represented by modelations of rock shield Morurco on the S. Cotopaxi slope,

c) young volcanic cone with top crater, with effusions of plain character and distinct eccentricity. Eccentricity appears not only with relation to the old level

but also in the area of effusions which have constructed the young cone. As a characteristic feature there is cyclization of effusions, origin of effusions, origin of ice cap with short glacier tongues and slope destruction by climatomorphogenous processes and under the influence of mud flows (lahars).

Volcano Cotopaxi represents a typical volcano of the Ecuador Andes. It is therefore a suitable starting object for correlation studies of development of structural levels and relief of the other Ecuador volcanoes.

Translation by Alexandr Tacl

References

HALL M. L. (1977): El Volcanismo en el Ecuador. Publicacion del I. P. G. H. Secc. Nacion del Ecuador, Quito.

HRADECKÁ L. et al. (1973): Výsledky výzkumné činnosti Expedice Cotopaxi 1972. Závěrečná zpráva ČGÚ, Praha.

HRADECKÝ P. et al. (1977): Geologický vývoj vulkánu Cotopaxi v ecuadorských Andách. Sb. geol. věd — G 29:7—31. ÚÚG, Praha.

HUMBOLDT (1838): Geognostische und physikalische Beobachtungen über die Vulkane des Hochlandes von Quito. — A. Asher, Berlin.

LYSENKO V. (1975): Pseudokras vulkánu Cotopaxi v Ecuadoru. Čs. kras 26:110—115. Academia, Praha.

— (1976): Der Pseudokarst des Vulkans Cotopaxi in Ecuador. Die Höhle 27:1:32—37. Wien.

MEYER H. (1907): In den Hochanden von Ecuador. — D. Reimer, Berlin.

REISS W. (1873): Über eine Reise nach den Gebirgen des Illinizas und Corazon, etc. — Z. Dtsch. geol. Gessel. 25:354—359. Hannover.

SAUER W. (1971): Geologie von Ecuador. — Gebr. Borntraeger, Berlin.

STÜBEL A. (1897): Das Vulkangebirge von Ecuador. — Geol. — top. aufgenomen und beschrieben. Leipzig.

WOLFF F. (1929): Der Vulkanismus. 2. — F. Entke, Stuttgart.

WOLFF T. (1892): Geografia y geologia del Ecuador. — Brockhaus, Leipzig.

Resumé

VÝVOJ VULKÁNU COTOPAXI V ECUADORU

R. 1972 působila v Ecuadoru vulkanologická „Expedice Cotopaxi" vyslaná MK ČSR. Hlavním cílem výpravy byl geologický a geomorfologický průzkum vulkánu Cotopaxi. Součástí průzkumu bylo uskutečnění dvou výstupů na vrchol vulkánu, prvosestup na dno 334 m hlubokého kráteru a srovnávací sběr z dalších lokalit spojený s výstupy na štít Rumiňahui (4 712 m), Chimborazo (6 297 m) a obtížně dostupný nejaktivnější vulkán Jižní Ameriky — Sangay (5 437 m).

Průzkum Cotopaxi probíhal v součinnosti dvou skupin: geologické, zaměřené na petrografii a chemismus stavebních pater vulkánu, a geomorfologické, sledující vývoj reliéfu vulkánu.

Cotopaxi je situován v západní části východního horského pásma And, označovaného Cordillera Real, 50 km jižně od Quita, 35 km sv. od města Latacungy. Území vulkánu leží v klimatickém pásmu páramo při západním okraji oblasti srážkového maxima v Ecuadoru. Na východních svazích se pohybuje průměr ročních srážek od 2 000 do 2 500 mm, na západě kolem 1 500 mm. Drsnější klimatické poměry na východě a na jv. svazích ovlivňují i čáru věčného sněhu, která zde klesá až na 4 500 m, zatímco na sz. svazích vystupuje do 4 800 m. Územím vulkánu také probíhá recentní rozvodí mezi Tichým a Atlantským oceánem.

Výška vulkánu je 5 897 m, průměr báze je 22 km. Je to typický stratovulkán s historicky doloženými periodami zvýšené aktivity. Erupce mají většinou vulkánský charakter, stadia klidu jsou nepravidelná a často značně dlouhá. Poslední efúze lávy je z r. 1942, podstatně zvýšené exhalace v oblasti kráteru byly zaznamenány v r. 1975.

U vulkánu lze rozlišit relikty starého stavebního patra (stáří miocén, pleistocén až mladý pleistocén) se zachovalými tvary pleistocenní glaciální eroze a vlastní mladý vulkanický kužel (holocén až recent) s ledovcovou čapkou a vrcholovým kráterem.

Relikty starého stavebního patra se vyskytují na obvodu recentního kužele, kde jsou obnaženy ve stěnách kaňonů v jižní části a na dně ledovcového údolí Rio Pita. Výrazně vystupují jako skalnatý štít Morurco. Geologicky je tvoří 4 komplexy vulkanitů odlišného stáří a petrografického složení (komplexy Aminas, Salitres, Morurco, Ingaloma). Nepřesahují výšku 4 800 m. Za stopy nejstaršího zalednění lze považovat modelaci neckovitého údolí Rio Pita a Limpio Pungo se zachovanými skupinami nunataků.

Mladý vulkán geologicky tvoří tzv. komplex Cotopaxi, u kterého rozlišujeme pět dílčích stavebních pater. Hlavní masu vulkanitů tvoří pyroxenické andezity — blokové lávy s plošinovým charakterem výlevů v úpatních částech svahů a stupni v horních partiích barrancos. Znakem efúzí je cykličnost a excentricita plošného rozsahu výlevů vzhledem k ose recentního vulkánu. Destrukci svahů podporují radiální ronové rýhy, v oblasti čáry věčného sněhu krátké ledovcové splazy, které sestupují z ledovcové čapky. S obdobím aktivity vulkánu je spjat vývoj rozsáhlých bahenních proudů. Základní tvary reliéfu jsou na obr. 2.

Kráter Cotopaxi má v průměru 800 m. Hloubka od vrcholu vulkánu je 334 m, od okrajového valu na západě 226 m. Kráter tvoří vnější somma a vložený vnitřní kráter. Hloubka vnější části je od vrcholu 212 m, od západního okrajového valu 104 m. Hloubka vnitřního kráteru je 122 m. Vnitřní kráter má průměr kolem 250 m. Na úpatí severní stěny a na západní straně kráteru fungovaly v r. 1972 solfatary s H_2O, H_2S a SO_2 o teplotě 80 °C. Z mělkého jícnu na dně a na svazích sommy vyvěraly plyny s převahou vodních par o teplotě kolem 40°C.

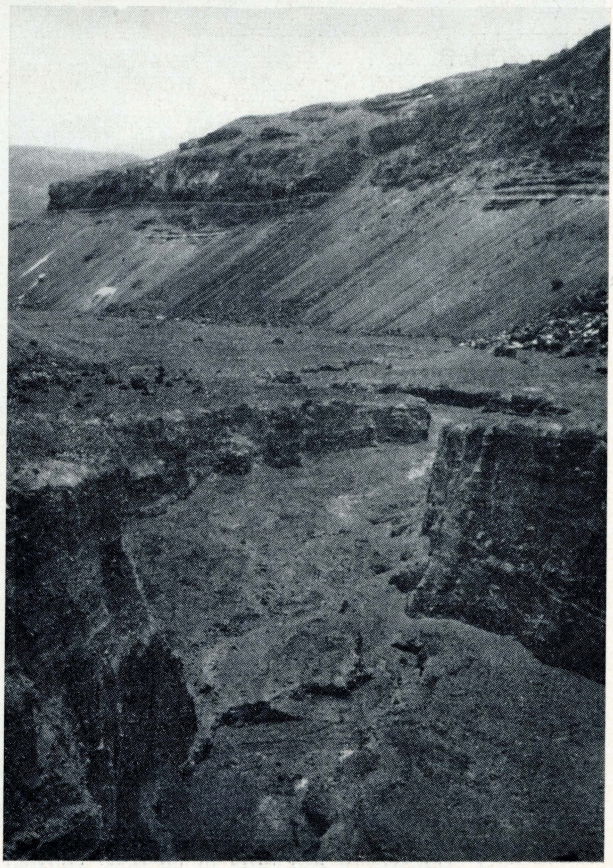
Vývoj vulkánu Cotopaxi začleňujeme do hlavní vulkanické fáze v Andách, která započala koncem třetihor (pliocén) jako doprovodná aktivita kečuánského vrásnění. Jako aktivní se projevují systémy paralelních zlomů, z nichž pro Cotopaxi jsou podstatné S—J a SSV—JJZ. Charakteristickým znakem vývoje této mladé fáze vulkanismu v Ecuadoru je změna chemismu vulkanitů, kdy obecně stoupá bazicita efuzív i pytroklastik od ryolitů či trachytů přes dacity, amfibolické či pyroxenické andezity až po bazické pyroxenické andezity, které někdy přecházejí až do olivinických čedičů. Tento vývoj je v zásadě zachycen u vulkánu Cotopaxi (tab. 1.), který má zachovaná všechna stavební patra s tím, že nejstarší komplexy (Aminas, Salitres) představují produkty plochého vulkánu s cenetrem cca 4 km jjz. od aktivního centra současného vulkánu. Hlavní glaciální eroze starého patra spadá do II. a III. stadia zalednění And starého a středního pleistocénu.

To the article *V. Lysenko:* Development of the volcano Cotopaxi in Ecuador

1. Cotopaxi from the S.S.E. direction. Ventanillas area modeled by glaciofluvial erosion with preserved volcanites of Morurco and Salitres complex.
2. Area of the Ventanillas on the N. Cotopaxi slope. In the middle photograph part there are observable distinct relicts of erosion steps bound with the Rio Pita valley development.

3. Salitres in the N.W. volcano part. The flat Rio Pita valley is filled predominantly by glaciofluvial sediments. Hummocky formations are relicts of glacial modelation (nunataks) built by volcanites of the complex Morurco and Salitres.
4. Salitres area. Glacial modelation of the Rio Pita valley. Pleistocene volcano Pasocha is in the background. Recent sinking of river is marked by arrow.

5. Tephras of Cotopaxi complex in the S.W. volcano part (Sta. Barbara) exposed by young erosion. Rock shield Morurco in the background, relict of the original volcano.



6. Mouth of the slope valley in the N. volcano part. On the uncovered walls there exist flows of block lavas of Cotopaxi complex.

7. Outcrop of ash tuffs in he N.W. volcano part.

8. Cirque slope valley head with distinct steps formed by lavas of Cotopaxi complex.
9. Valley in the N.E. volcano part. A stout flow of pyroxenite andesites of Cotopaxi complex forms a distinct step which was destroyed by retrogressive erosion.

10. Valley modelation in the N. E. volcano part. Glacier tongue passing into the upper valley part has trough-shaped form. Steps are formed by lava flows.

11. Profile through erosive cut in the Limpio Pungo valley on the N.W. volcano hill-side. Beds of ash and lapilli tephras alternate in the lower part, in the middle profile part they are eroded and covered by a chaotic lahar material.

(All photos by V. Lysenko)

To the contribution V. Lysenko: *Development of the Volcano Cotopaxi in Ecuador*

Encl. 1. *Geomorphological map of the volcano Cotopaxi* (Lysenko 1973).

Explications: 1 — external rampart, 2 — inner rampart, 3 — the youngest effusions, 4 — relicts of the old volcanic level, 5 — indistinguished volcanites, 6 — rock shield with features of glacial erosion, 7 — platforms of effusions of „main andesites", 8 — cirques and cirque steps, 9 — relicts of cirque steps, 10 — hanging valleys, 11 — girland soils, 12 — thufur field, 13 — nunataks, 14 — indistinguished moraine material, 15 — erosion steps in canyons, vertical canyon walls, 16 — valley filled up by glaciofluvial sediments, 17 — valley flat bottom, 18 — barrancos — ravines, 19 — barrancos — shallow furrows, 20 — lakes, 21 — mud flows — lahars, 22 — main directions of mud flows, 23 — glacifluvial dejection cones, 24 — debris avalanches, screes, 25 — dish-shaped well springs, 26 — area with the pseudokarst modelation, 27 — cave, 28 — swallow hole, outflow, 29 — wind-blown sediments, 30 — fumarolic and solphataric exhalations.