GEOGRAFICKÝ ČASOPIS

ROČNÍK 41 1989 ČÍSLO 4

ŠTÚDIE

JORGE F. CERVANTES-BORJA, MAGDALENA MEZA-SANCHEZ, GLORIA ALFARO-SANCHEZ*

DENUDATIONAL PROCESSES DURING THE LAST 20.000 YEARS IN THE BASIN OF MEXICO, MEXICO

Jorge F. Cervantes-Borja, Magdalena Meza-Sanchez, Gloria Alfaro-Sanchez: Denudational Processes During the Last 20,000 Years in the Basin of Mexico. Mexico. Geogr. Čas., *41,* 1989, 4; 4 figures, 1 table, 12 refs.

The Basin of Mexico is one of a serie of continuous tectonic basins in central Mexico territory. Formed by the disruptions of the Pliocene and Pleistocene volcanic activity. The broad, pyroclastic-alluvial and lacustrine sediments filled the basin which is surrounded by volcanic (andesitic) highlands, which attain an elevation over 4000 m.a.s.l. Its floor lies at an altitude of 2240 m.a.s.l. Sediment in and around the margins of the basin, provides a record of alluvial conditions extending over Holocene period. Examinations of these deposits provides information on the erosional procedure in terms of their sediments source. Key elements of this study includes: Tectonic activity and climate changes during the upper Pleistocene and Holocene periods and its effects on erosional and depositional processes. Finally deducing the soil formation periods by correlation with terrace sequences.

INTRODUCTION

This work presents a geoecodynamic zonation resulting from match two points of view: On one hand, we are considering the inheritance of paleoenvironments, prevailing in soil characteristics, and on the other, the morphoclimatic and geological (tectonic-volcanic) processes and its influence to breach the soil forming system. The analysis go back for about 30 000 yr. B. P. in order to the age of the oldest soils.

The Basin of Mexico is a complex tecto-volcanic structure forming back to Eocene period. Tectonic activity result of Cocos and North American plates interaction. Oceanic crust is being subducted northeastward from the meso-

*Dr. Jorge F. Cervantes-Borja, Dr. Magdalena Meza-Sanchez, Dr. Gloria Alfaro-Sanchez, Universidad Nacional Autonoma de Mexico, Instituto de Geografia, Ciudad Universitaria, 04510 Mexico D. F., Mexico.

american (Acapulco) trench which terminates off the Tehuantepec crest. The igneus activity (andesitic lavas), may be derived from melting of the oceanic Cocos plate, forming an ancient zig-zag suture called „Mexican Volcanic Belt“, which has been reopened since Tertiary times (Mosser 1972).

The basin has three principal geomorphic units (Lopez 1975, Cervantes 1983).

1. Chain mountains (Major and Minus, Pg/N/Q)
2. Transitional talus (upper, medium, lower, N/Q)
3. Plains (local base level of depression fosse, Q)

There is a differential climatic influence through altitude levels, which has it for around 3000 meters. For this reason the mesoclimatic types were made considering the spatial integration both isotherms and isohygromens which take account the isohyets, soil water balance and topographical conditions, in order to establish better ecological patterns to vegetation distribution. Below 19 °C isotherm, the climate types are warmer with tropical deciduous forest and finally xerophytes formations. Over this temperature limit, the climate is cold under tropical influence and with coniferous forest. Timber line is over 5 °C isotherm, 4000 m.a.s.l and snow line begins at 0—1 °C isotherm ± 4900 m.a.s.l., between them an open grassland is developed.

The arid cold climates during the latest Pleistocene (34.000 yr B. P.), increased erosional processes over the mountains particularly below 4000 m.a.s.l. (Heine, and Heide Weise 1973). Where it had a periglacial environment, with intensive morphogenetic processes who reached talus deposits and graded the hillslopes.

The change to humid low energy condition between 34 000—22 000 yr B. P. left an aggradational phase with soil forming process in which a dense coniferous forest mantled the mountains between 2350—4500 m.a.s.l. After 22 000 yr B. P. the humid decrease and the climate turn colder and dry again until 14 000 yr B. P. Humid and cool conditions was present from 1400 to 8000 yr B. P. The Holocene begins with warmer and humid condition.

PALEOCLIMATIC DATA

Paleoclimatic evaluations have been made primarily through pollen studies, dating of glacial advances, and changes in snowline altitude. Lauer (1973) indicates that the snowline in the eastern mountains was about 800 meters lower than at present in the last full glacial, and tree line currently at 3800 meters, in the involve talus range, probably was depressed in a similar amount. Depression of mean annual temperatures of 4.5—5.0 °C contributed to the harshness of full glacial climates. Restriction of forest were in lower depressions by salt water, and north facing hillslopes also caused by droughts, strong winds and severe frosts during outbreaks of freezing polar air masses during growning seasons. Full glacial plant communities of sparse grasslands herbfields became grasslands and partial shrubland at roughly 14 000 yr ago, as harsh conditions began to ameliorate during a period that was transitional between glacial and interglacial climates.

Pollen studies reveal markedly different plant associations between upper Pleistocene and Holocene. From 44 000 to 12 000 yr B. P., had a homogeneous flora, characterized by abundant *Pinus, Quercus* and *Juniperus* (Gonzalez Quintero 1980, Brown 1985, Watts and Bradbury 1982). This represent and appreciable subhumid and colder climate than present. Pleistocene ends with two drier-humid glacier phases between 10 000 to 8500 yr B. P. (Heine and Heide-Weise 1973). Before 10 000 yr B. P. diatoms indicate cool and dry climates in consequence the Chalco basin was occupied by a shallow fresh watermarsh. This lake drained north to Texcoco lake, where salines were formed by evaporation (Bradbury 1986).

The Holocene represents an increase in Pinus pollen and diminished of *Quercus* and *Juniperus. Alnus,* was abundant after 8000 yr ago under Optimal Climatic Epoch (Heine and Heide-Weise 1973); its abrupt decrease with the first presence of herbaceus weed pollen may reflect of cultural activities simply reflect a drying tendency in the climate, after 4000 yr B. P. pollen of Zea, appears at lake of Texcoco with frequently peack of Chenopodium and grass pollen at 3500 yr B. P. (Gonzales Quintero 1980). The last minus glaciation 2000 yr B. P. more humid than present was favourable to *Abies* forest, after it warm and dry tendency and cultural activities restricted this forest.

Diatom stratigraphy from Chalco basin, Bradbury (1986) indicates fluctuation in lake levels and chemistry in response to variation in available moisture regime: The lake of Texcoco flooded the Chalco basin with brackish water.

After 2000 yr. B. P. such flooding decrease, and shallow freshwater ponds and marshes were restored in the Chalco basin. This environmental change coincides with increments of *Zea* pollen and indicates an important cultural influence.

All Quaternary volcanic activity and tectonic movements modified the local base level. For upper Quaternary climatic changes and rapid movements promote a diversity of adjusments in the drainage system, because aggradation--denudation phases which balance today show negative results to developing edaphic processes.

Herency of many cuts (four big ones), with terraces over the mountains gives cuts over 300 m depth. Each broad represents first volcanic deposits layered in semiequilibrium conditions attained by the powerful streams during the interglacial phases, but without despite episodes of being overwhelmed during full-glacial climates, both induces to maintain a long-term degradation rate quasiequal to the uplift rate. The active fault system and the volcanic deposits separate the drainage into the basin and talus (piedmont). This processes had been highly active with rates of hundred meters of horizontal and vertical displacement.

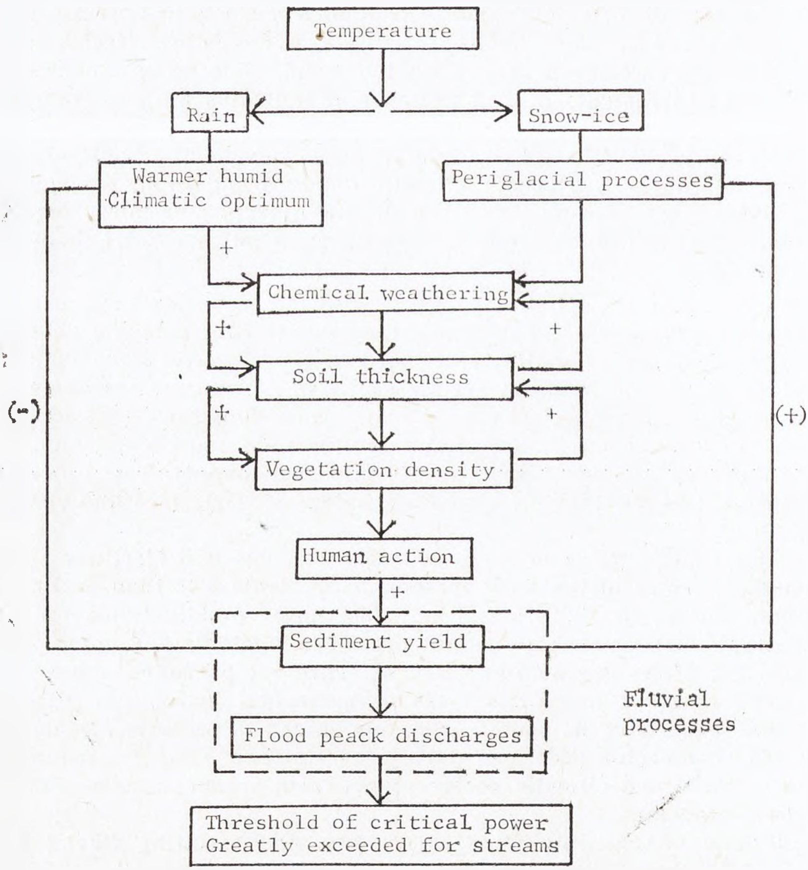
The major relief amplitude value over 400 m., Lugo and Martinez (1982), represents the amount of the local tectonic movements less than a climatic fluvial action. During the Pleistocene and principally middle Holocene the morphoclimatic erosion reaches gorge cuts over 60 m in middle and upper talus over the mountains. Many degradation terraces represent pauses of a few centuries in Holocene downcutting. Rapid rates of horizontal inclination displacement of the talus reach from its source area, has helped to preserve stream terraces that record geomorphic processes during the Holocene, and the magnitudes of both the tectonic and climatic perturbations have produced strong impacts on geomorphic processes.

The climatic change into tropical regimen and resulting fluvial response occurred at the same time that continuing uplift increases the tendency for valley floor downcutting. Although uplift continued, downcutting could not begin until aggradation had ceased. Since then, the rivers of the basin have tended to catch up again with the long term amounts of valley downcutting dictated by local uplift rates.

METHODS AND MATERIAL

Geomorphological and hydrogeological investigations of the area under study were carried out by means of a combination of aerial photointerpretation and field transverses and cartographic work. Detailed geomorphological, hydrogeological, pedological and geoecological maps were produced to prepare

Figure 1. A process-response model for the mountains and upper hillslope talus of the Mexico's basin for a change from semi-arid and frigid to humid and mesic conditions.



a denudational evolution balance for the region. The various natural parameters of the sampling points were studied and interpreted in relation to the geomorphic units and its relative landscape.

Geomorphological chart was prepared using the C.G.A. Strassbourg France method (1963). Pedological chart uses the USDA, Soil Survey Staff method (1975), Hydrogeological analysis was prepared by use of Horton's and Strahler's indexes and Hack's stream gradient index (Hack 1973).

DRAINAGE BASIN ADJUSTMENTS TO CLIMATIC CHANGE AND TECTONISM

During the late Quaternary over the piedmont had established all three modes of stream operation: Aggradation, degradation and equilibrium or grade. Equilibrium reaches are associated with stable longitudinal profiles, and aggradation and degradation are disequilibrium processes that occur where insufficient time has elapsed for interactions between variables to result in equilibrium conditions.

Prior longitudinal profiles of valley floors are represented by the treads of fill, cut and strath terraces. Treads of fill terraces represent the time of change from aggradation to degradation.

Cut (in alluvium), and strath (in bedrock) terraces represent the principal climatic or tectonic morphogenetic adjustments. Lateral erosion and minimal downcutting represents relatively brief pauses during an interval of downcutting.

When resisting power exceeds stream power, aggradation of bed load occurs as the suspended load is washed downstream (see Figure 1). Thus the deposits of fill terraces consists of bed load materials. Both tectonic and climatic change affect the components of the threshold of critical power. Uplift tends to increase slopes, and cooler and/or wetter climates generally increase streams discharge. Thus, changes in the amount and size of sediment yielded from hillslopes may be caused by either tectonic or climatic changes, but resisting power also varies with changes in hydraulic roughness that are independent of tectonic and climatic controls.

HILLSLOPE CHANGES (MOUTAINS AND UPPER-MEDIUM TALUS)

This section considers possible interactions between variables that would account for large-scale aggradation and subsequent degradation by the fluvial process. The proposed model is consistent with the present knowledge of former climatic and vegetation conditions with the presence of volcanic, colluvium and alluvium deposits in valleys eroded into piedmont.

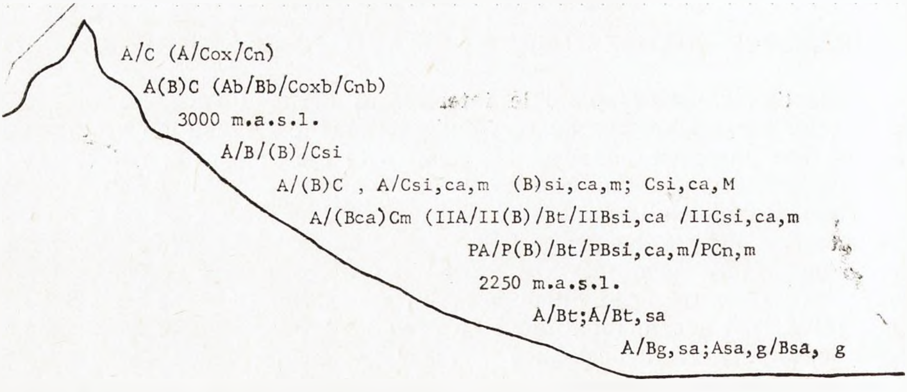
Detritus on steep hillslopes tended to accumulate when forest were present and to be largely removed when erosional processes were active on treelees slopes. Partial stripping of hillslope colluvial mantles over the mountains and upper talus, that accumulated during a previous milder climate were enhanced above seasonally by the presence of an active freeze-thaw layer. Infiltrating water from summer snowmelt or rain saturated colluvium above impermeable layers, thereby creating ideal conditions for mass movements and soil packs on hillslopes that were steep because of rapid mountain uplift. The resulting increases sediment yield caused major increases in resisting power, that tended to cause aggradation of valley floors during periglacial regimes; subsequent decreases appear to have been associated with degradation of valley fills.

The likely effects of the Pleistocene-Holocene climate change allow us to construct a process-response model the 88 % of the Mexico's Basin between 2800—4000 m.a.s.l (see Figure 1). Treeline varied during the Holocene less than Pleistocene above the 4200 m.a.s.l. during the mid-Holocene climatic optimum and lower than present during the latest Holocene glaciation transitional climate, above 2000 yr B. P.

The available regional and local data suggest the following scenery. Latest Quaternary climatic changes involved significant warming and less increase in total precipitation. These must have been sufficient to replace the mass movement hillslope regime associated with periglacial processes with a fluvial process regime, although landsliding probably remains like important source of sediment into the drainage system. Major increases in vegetation density occurred as bushes and then trees, returned to form a protective vegetative cloack on the hillslopes. Warmer and wetter climates, increase the organic acids and the rates of chemical weathering of hillslope colluvium and bedrock. Return of forest would initiate hillslope aggradation in which increases in soil thickness further tended to increase vegetation density, thus increasing sediment storage on hillslopes. The net effect of these changes was to greatly decrease hillslope sediment yield into the floor basin.

The latest Pleistocene and early Holocene decreases in sediment yield postulate in the flow diagram of Figure 2, would cause a major decrease in resisting power at a time of climatically induced increases in stream power. Sustained high discharges were possible during the summer melting of late Pleistocene snowpacks. But with the onset of Holocene climates, the proportion of precipitation that fell as rain increased, and this probably resulted in substantially larger flood discharges.

Figure 2. Distribution of soil profiles types in transect from the mountains to the plains



The return of tropical storms during the Holocene caused episodes of markedly greater stream power. Tropical storms may have been more common during the mid-Holocene climatic optimum than at present because warmer and humid air masses were favorable to the persistence of such storms.

STREAM ADJUSMENTS

Examination of outcrops provides a diversity of tectonic and climatic geomorphic information about the aggradation/degradation cycle on the Mexico's Basin. A well defined volcanic strath (Tacubaya deposit) is present along the talus which suggests that is a major strath formed during an earlier prolonged period of equilibrium Q_2^3. The lack of paleosols in the uniformly massive medium grained sandy gravels above the strath is suggestive of a single aggradation event. The late Pleistocene valley fill period are capped with a 1—2 m thick younger boulder bed, that reflects a totally different streamflow regime than that of the underlaying deposits (lower Tacubaya). Locations where the aggradation deposit was not partly eroded by Holocene downcutting, the total thickness is over 20 m.

Holocene degradation cut over 50 m below the level of the late Pleistocene strath to the active channel reveals the influence of long-term tectonic uplift on channel downcutting into the softbedrock of this reach.

In order to describe the stream adjustments in a quantitative manner it is necessary to obtain age estimates for the principal fluvial terraces. This was obtained by cobble — weathering — rind and soil profile parameters that were compared by bibliography radiocarbon dates from any sites.

The most useful datum for age control was the terrace — treads, which aproximate time lines in the landscapes of — stream systems and represent either the crossing of the threshold of critical power of periods that were close to equilibrium.

Organic material for radiocarbon dating are uncommon in the talus deposits, but it can provide stratigraphic ages. However this apparent advantage is offset by the necessity of having to estimate the elapsed time between the deposition of the dated organic matter and the formulation of the terrace tread.

Relative dating techniques involving time dependent processes such as superficial weathering of rocks and soils development become specially useful when rates are calibrated at sites of known ages. Weathering rings form rapidly both surface and subsurface. Ring thickness increases with age as a power

Table 1. Ages estimates from several terraces on talus deposits in the basin of Mexico

Altitude	Terrace	Age 10^3 years
200		
100 — 200	Aggradation	20.0 ± 2.0
40 — 100	one	10.0 ± 2.0
20 — 40	two	4.0 ± 0.5
0 — 20	three	0.5 ± 0.1

function and is useful for dating surfaces of landforms that are less than 20 000 yr, The table 1 gives the terrace tread probably formed after 20 000 yr. ago (±2000).

Only limited information is available regarding rates and timing of deposition during the latest Pleistocene aggradation event. Major straths seem to have forming during times of interstadial of interglacial climates (such as during the late Holocene), which suggests that the major strath beneath the latest Pleistocene, Tacubaya deposit about 20 000—30 000 yr. old corresponding to the last interstadial. Deposition on this strath occurred without sufficient hiatuses to allow soil profiles to form.

ASH-FALL DEPOSITS AND STRATIGRAPHIC LAYERS OF SOILS DERIVED FROM VOLCANIC ASH

Pyroclastic materials in ash-fall deposits have been spread widely. Although the Pleistocene deposits are extensive and thick, parts of them are deeply buried by one or more strata of Holocene ashes. In some areas, Holocene deposits occupy the surface, but Pleistocene deposits are still within the soils profiles like IIA, II(B), IIC, or PA, PB, and PC, horizons.

Soils may be divided into six broad orders on the basis of degree on weathering: Entisols (Cryortent, Litic, Ranker, Andic); Inceptisols (Umbrept, Aquept, Ocrept); Andisols (Ustands, Aquands); Vertisol (Ustert); Alfisol (Ustalf); Mollisol (Ustoll).

An estimation for differentiation of soil horizon sequence reflects the weathering age of the pyroclastic deposits as follow: (1) (2) (3) (4)

Time weathering	Soils horizons sequence
Less than 500 years	C or (A)/C
500—1500 years	(A)/C, A/C A(B)C
1500—3000 years	A/(B)/C or A/B/C
More than 3000 years	A/B/C

Atmogenic and hydromorphic soils resemble the surface water and the ground water type of soil formation, thus differ fundamentally in geomorphic position, geochemical accumulations and ecological properties and should be differentiated accordingly with climate and base level changes.

According with profile types distribution in transect from the mountain to the plains (see Figure 2), we have three pedogenetic areas, twice atmogenic, first over 3000 m.a.s.l. and the second between 3000 and 2250 m.a.s.l. The third type below 2250 m.a.s.l., occuped all the plains.

The transitional area over talus is the most exposed to the erosive processes as both climatic changes as tectonic movements, in archetype catenary sequence it would be like Figure 3.

The formation of the atmogenic type depends more on the rain intensity in relation to the resistance to flow of the soils, which is determined by the saturated hydraulic conductivity, upper the mountains and by the field capacity in the talus.

For the hydromorphic type the total rainfall and the size of the catchment

Figure 3. Archetype catenary sequence from the mountains to the plains

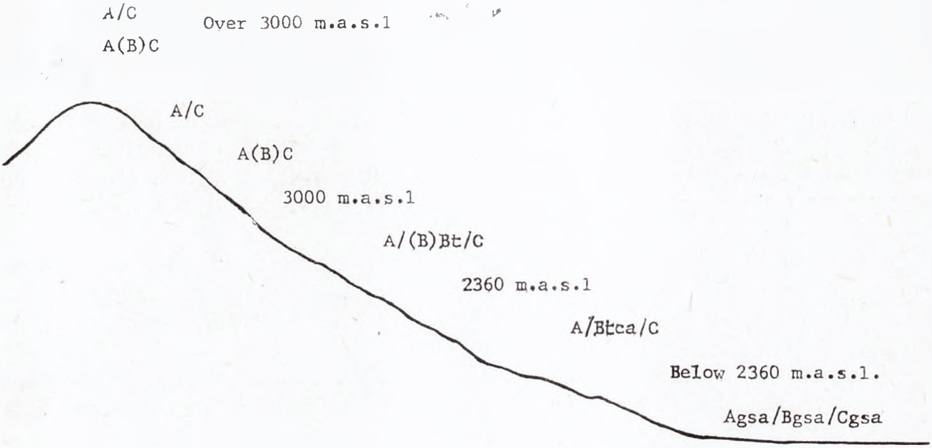
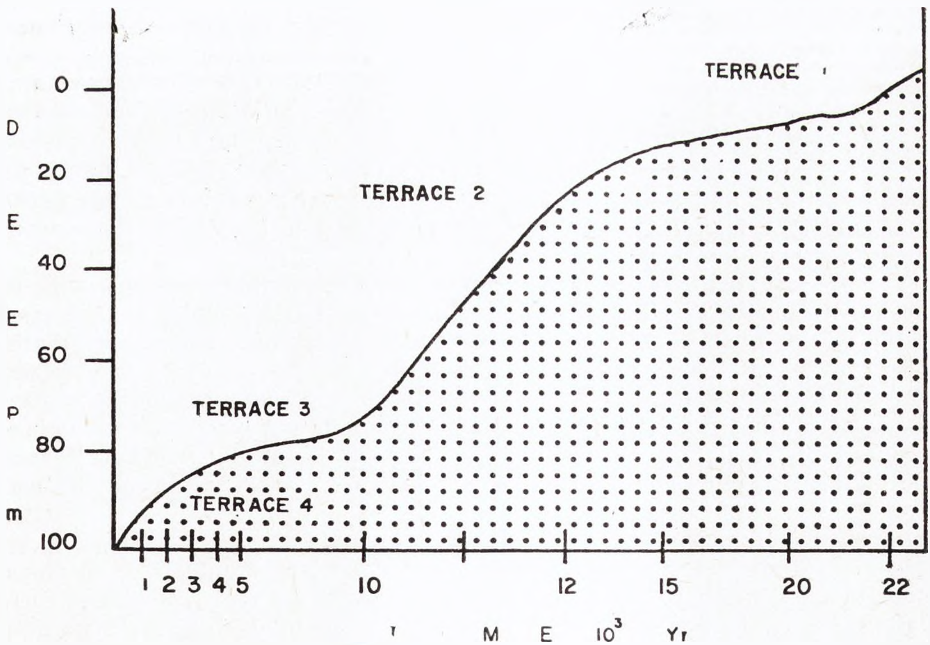


Figure 4 Generalized downcutting curve The crosses mark possitions of terraces forming during brief pauses in downcutting, and estimated degree of uncertainity of the terrace ages distances below the aggradation surface, which serves as the reference level



area, are more important, and the pump effect may be caused by the evaporation specially by the textural loamy with high capillary conductivity, concerning the geomorphic relationships, the two types differ not only in the topography, but in the age of the land surfaces as well: whereas the atmogenic accumulation is restricted to relatively old surfaces, the hydromorphic one can already occur on rather young ones (both the more mobil the relevants solutes are).

Specially in older valleys a fundamental geo or pedochemical difference becomes important: whereas the atmogenic type is autonomous (except for eolian inputs never is richer than its parental material), the hydromorphic one is dependent on its catchment area, thus may be enriched even with rather rare constituents.

To this degradational history. Figure 4, that depict the ability of powerful streams to downcut through aggradation phases and underlying bedrock as it attempts to catch up with the past 30 000 yr tectonic uplift and establish a new equilibrium condition.

The presence of valleys fills both upstreams and downstreams from the upper to lower talus is in accord with the climatic change cause for the 2 and 1 aggradation phases.

The only tectonic control (phases 4 and 3) may have been displacements that favoured the formation of alluvial fans near the head of the upper talus reach. These fans and the related valley fills thin progressively downstreams till the medium talus.

Ages and heights of the four principal terraces were used to reconstruct the degradational history of the last 20 000 yr. Total degradation is > 100 m; 60 m through the upper Pleistocene, and 40 m through the Holocene. We have fit generalized smooth curve.

Initially slow degradation rates were followed by a pronounced last Pleistocene acceleration in channel downcutting and decreasing during the Holocene.

Stream power and resisting power were the same at the time of the threshold crossing at about 22 000 years ago, and stream power probably exceed resisting power between 22 000 to 14 000 years ago.

Stream power was much greater than resisting power between 14 000 and 8000 years ago, and the rivers rapidly downcut more than 40 m in this period, and more than less 20 m, till 2000 years ago. The 9 m average of downcutting during the last 2000 years gives an order than 4.5 m/1000 yr.

The upper Pleistocene episode of maximum downcutting coincides with the period of climate that are estimated to be about 1—2 °C colder than present.

During this climate optimum, the highest hillslopes may have been mantled with forest, and the frequency of intense rainfalls derived from tropical moisture sources may have been greater than present. Vegetation has little effect on runoff during extreme storms events. But vegetation can be important factor in greatly reducing sediments yields during major storms. For both reasons the Pleistocene ends may have been a period of maximum difference between streams power and resisting power.

During the Holocene the streams tended to remain strongly on degradational side of the thresholds of critical power, but short term fluctuations in one or more factors may have been temporarily decreased the ratio of streams to resisting power, thereby moving the streams closer to equilibrium conditions.

Possible changes include a decrease in rainfall that would decrease runoff and stream discharge, a brief return of colder climate that would increase sediment yields, and seismic movements (tecto-volcanic) triggered landslides that would introduce large volumes of additional sediment into the mountains stream channels.

Although the above possibilities cannot be eliminated as causes for one or more of the Holocene equilibrium terraces. The field evidence suggest another explanation that does not require changes within drainage — basin reach.

Each of the degradational terraces may have been associated with self-arresting feedback mechanisms that greatly increased resisting power. The poorly sorted sandy medium grained gravels of the aggradation episode suggest rapid accumulation in an environment of sligth to moderate winnowing and sorting by stream flows the gravels associate with the degradational terraces commonly are bouldery caps on uderlying aggradation gravels of bedrock.

Winnowing of alluvial gravels during periods of moderate stream flows would be accompanied by input of additional cobles and boulders.

The resulting streambed armor would greatly affect bedload transportation and channel degradation rates. Resisting power would be increased by:

a) the increases in size material to be entrained by stream flows,
b) the relatively close spacing of large particles,
c) concurrent increases in hydraulic roughness from approximately 0.025 to about 0.035,
d) growth of valley floor vegetation as the streames become temporarily stabilized, which further increases hydraulic roughness.

Increases in resisting power continue as a self-arresting feedback mechanism until resisting power equals stream power for the spectrum of stream discharges available to transport bedload sediment.

Renewed degradation probably was initiated by a low event sufficiently large to disrupt and destroy streambed armor and remove valley's floor vegetation.

Storm events with a return period of several hundred years would a low sufficiently time for the formation of armored streambeds and minor terraces during pauses in downcutting.

CONCLUSION

Our data and concepts can be summarized by estimating the changes in the relative magnitude of stream power and resisting power during the last 20 000 yr ago. The plot of relative stream power and resisting power assumes that the tectonic setting climate and geomorphic processes were similar during times of major interglacial and interstadial climates; and that these were also periods of major constructional development during prolonged attainment of equilibrium conditions in the fluvial subsystem. These general constraints dictate that stream power and resisting power plots are identical before 20 000 yr, and during the last 8 000 yr.

Vertical separations between the stream power and resisting power plots indicate how far were removed the talus deposits from equilibrium or thresholds conditions. The magnitudes of these vertical separations are directly proportional to the slope of the overall degradation curve of figure 4. A single threshold of critical power is indicated where the two plots cross, and equilibrium conditions are indicated wherever the plots are horizontal and have the same value. Patterns of relative changes of stream and resisting power would be generated by assuming:

(1) a different climate 22 000 yr ago,
(2) less decrease in resisting power between 22 to 14 000 yr ago, and
(3) lack of abrupt decreases in resisting power associated with decreases in hydraulic roughness between 8 to 2000 yr ago.

Two domains of behavior for the morphogenetic system reach were an aggradational mode of operation persisted from shortly after 2000 yr ago until about 1100 yr ago.

Stream power decreased with the onset of a cold dry climate that led to full-glacial conditions. Reductions in annual precipitation and in the proportion of the precipitation falling as rain combined to reduce the fluvial peacks substantially. The subsequent transitation to warmer wetter Holocene climates reversed these decrease in fluvial process but aggradation until streams power and resisting power crossing at the 9000 yr threshold.

The cause of concurrent latest Pleistocene increase in resisting was the increase in sediment yield derived from the active periglacial processes on hillslopes.

This trend also was reversed with the onset of transitional climates. Thus, the time of full glacial climate was also a time of maximum aggradation rate, which is not an easily recognized parameter in the stratigraphic record. The threshold crossing associated with the tread of the fill terraces ocurred during the latest Pleistocene climatic transition, by which time as much as 100 m were accumulated.

The post 4 000 yr domain has more a complex pattern that reflect about 40 m of intermittent channel downcutting.

Our knowledge of geomorphic change during the period is more detailed because of the many possible study sites in a fligth of degradation terraces as compared to the stratigraphy of gravels of a single aggradation event. Stream power remained high during the Holocene relative to the latest Pleistocene, because of increased precipitation, and because more of the precipitation fell as rain instead of snow.

The mid-Holocene warm period between 8000—3500 yr ago, represented a climatic optimum that further accentuated the difference between streams power and resisting power. The time span between 1500 to 900 yr ago, is specially noteworthy because of the 16 m degradation during this period. The mid-Holocene climatic optimum may have been a time of increases incide of major storms runoffs associated with tropical moisture sources.

The overall trend during the Holocene may have been for progressively decreasing sediment yield from the hillslopes as soils tended to thicken and improve, thereby increasing the density of forest vegetation.

The decreases in sediment load were the primary cause of the overall decline of resisting power since full — glacial times, but resisting power fluctuated sharply. It increased during times of stream beds armoring and plant growth which increased hydraulic roughness and the shear stresses needed to entrain streambeds materials. Each major flood discharge that disrupted streambeds armors caused an abrupt decrease in resisting power that was gradually renewed during the subsequent period of degradation and concurrent streambeds armors.

Thus it appears that the fligth of minor Holocene cut and strath paired terraces was formed by episodes of self-arresting feedback mechanisms. Climatic variations and movements along the hope fault did not directly affect attainment of episodic equilibrium conditions in the general talus.

REFERENCES

1. BRADBURY, J. P.: Paleolimnología del lago de Chalco, Mexico. El medio ambiente litoral. En Tlapacoya 35 000 anos de Historia del lago de Chalco. Col. Cientifica INAH. SEP. Serie Prehistoria, 1986, pp. 167—172. — 2. BROWN, B. R.: A Summary of Late--Quaternary pollen records from Mexico west of the Isthmus of Tehuantepec. in Pollen Records of Lake-Quaternary North American Sediments. By AASP Foundation, USA, 1985. — 3. (CGA), CENTRE DE GEOGRAPHIE APPLIQUEE. Legendes des cartes Geomorphologiques detailles. Strasburg, 1963. — 4. CERVANTES, B. J. F.: Génesis, morfología y clasificación de los suelos de la Cuenca de México. Tesis Doctoral en Ciencias (Biología). Facultad de Ciencias, UNAM, México (Inédita), 1983. — 5. CONZALES, Q. L. y FUENTES, M. M.: El Holoceno de la porción central de la Cuenca del Valle de México. Mem. del III Coloquio sobre Botánica y Palinologia, SEP. INAH. Depto. de Prehistoria. Col. Cientifica, *86,* 1980, pp. 113—132. — 6. HACK, J. T.: Stream profile analysis and stream gradient index. Journal Research, U. S. Geol. Survey, *1,* 4, 1973, pp. 421—429. — 7. HEINE, K. and HEIDE-WEISE, H.: Secuencias de erupciones en el Volcán de la Malinche y en la Sierra Nevada durante los últimos 40,000 años. Comunicaciones, Proyecto Puebla-Tlaxcala, *7,* 1973, pp. 7—8. — 8. LOPEZ, R. R.: La Cuenca de Mexico. Medio fisico natural. En Memorias del Plan Director del Departamento del Distrito Federal, Mexico, D. F. 1975. — 9. LUGO, H. J. y MARTINEZ, L., V. M.: La disección del relieve en el sur de la Cuenca de Mexico y poblaciones adyacentes. Bol. Institute de Geografia, UNAM, *10,* 1981, pp. 55—64. — 10. MOOSER, F.: The Mexican Volcanic Belt: Structure and tectonics. Geofisica Internacional, *12,* 2, 1972, pp. 55—70.
11. USDA: Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys. 175. Washington, 1975. — 12. WATTS, S. W. A. and BRADBURY, J. P.: Paleoecological studies at lake Patzcuaro on the west Mexican Central Plateau, and at Chalco in the Basin of Mexico. Quaternary Res., *17*, 1982, pp. 56—70.

Jorge F. Cervantes-Borja, Magdalena Meza-Sanchez,
Gloria Alfaro-Sanchez

DENUDAČNÉ PROCESY POČAS POSLEDNÝCH 20 000 ROKOV V MEXICKEJ KOTLINE, MEXIKO

Mexická kotlina je jednou zo série tektonických kotlín v centrálnej časti Mexika. Vytvorila sa rozlámaním počas pliocénnej a pleistocénnej vulkanickej činnosti. Kotlinu vyplňujú pyroklastické riečne a jazerné sedimenty a ohraničujú ju vulkanické (andezitové) vysočiny, ktoré dosahujú nadmorskú výšku vyše 4000 m. Dno kotliny leží v nadmorskej výške 2240 m. Hoci územie bolo umelo odvodnené smerom na severozápad, v centrálnej časti kotliny, v blízkosti metropolitnej oblasti Mexico-City sa zachoval zvyšok jazera (Texcoco). Sedimentačné a geomorfologické dôkazy poukazujú na to, že kotlina bola v minulosti zaplavená rozsiahlym jazerom. Zmeny v potenciálnom hydrologickom systéme, a teda aj v eróznych procesoch a režime jazera boli spôsobené tektonickými, klimatickými a antropickými faktormi. Staré osídlenie významne vplývalo na pôdnu eróziu intenzívnym využívaním zeme. Nerovnovážne podmienky sa vytvorili činnosťami človeka. Skombinovali sa tri faktory, ktoré modifikovali alebo rozrušili pôdnu pokrývku Mexickej kotliny, a to:

1. tektonicko-vulkanické zdvihy,
2. klimatické zmeny,
3. ľudské sídla s vplyvmi pastierstva a roľníctva.

Riečne podmienky počas celého holocénneho obdobia zaznamenali sedimenty v kotline a na jej okraji. Skúmanie týchto uložení́n poskytlo informáciu o eróznych procesoch a zdrojoch materiálu.

Kľúčové prvky tejto štúdie zahrňujú predovšetkým tektonickú činnosť a klímu, ktoré sa menili počas vrchného pleistocénu a holocénu, čo ovplyvňovalo erózne a akumulačné procesy. Pôdna pokrývka sa formovala súbežne s formovaním terás.

Obr. 1. Model process-response pohorí a horných osypov pahorkatinového svahu v Mexickej kotline a zmeny od semiarídnych a studených k vlhkým a miernym podmienkam.
Obr. 2. Distribúcia typov pôdnych profilov na transekte z pohorí do nížin.
Obr 3. Archetypová katénová sekvencia z pohorí do nížin.
Obr. 4. Generalizovaná krivka zarezania. Kríže označujú pozície terás formujúcich sa počas krátkych prestávok v zarezávaní; odhadnutý stupeň neurčitosti veku terasy označuje vzdialenosti pod agradačným povrchom, ktorý slúži ako referenčná hladina.

Tab. 1. Určený vek z rôznych terás na sutinových sedimentoch v Mexickej kotline.

Хорхе Ф. Сервантес-Борха, Магдалена Меза-Санчез,
Глория Альфаро-Санчез

ДЕНУДАЦИОННЫЕ ПРОЦЕССЫ В ТЕЧЕНИЕ ПОСЛЕДНЫХ 20 000 ЛЕТ В МЕХИКАНСКОЙ КОТЛОВИНЕ, МЕКСИКА

Мехиканская котловина представляет собой одну из серии тектонических котловин в центральной части Мексики. Она образовалась вследствие разлома во время плиоценовой и плейстоценовой вулканической деятельности. Котловина заполнена пирокластическими речными и озерными отложениями и окаймлена вулканическими (андезитовыми) высокогорьями, достигающими высот более 4000 м над уровнем моря. Дно котловины расположено на высоте 2240 м над уровнем моря. Несмотря на то, что территория была исскуственно осушена в направлении к северо-западу, в центральном участке котловины, вблизи столичного региона Мехико-Сити, сохранились останки озера (Техкоко). Седиментационные и геоморфологические доказательства указывают на то, что в прошлом в котловине находилось обширное озеро. Изменения в потенциальной гидрологической системе, а значит, также в эрозионных процессах и в озерном режиме, вызваны тектоническими, климатическими и антропогенными факторами, Древнее расселение важным образом влияло на почвенную эрозию вследствие интенсивного использования земель. Условия неравновесия возникли в результате деятельности человека. Скомбинировались три фактора, модифицирующие или разрушающие почвенный покров в Мехиканской котловине:

1. тектоническо-вулканические поднятия, 2. климатические изменения, 3. человеческие поселения с пастушеским и земледельческим влиянием. Отложения в котловине и в ее окрестностях подвергались речному воздействию в течение всего голоценового периода. Изучение этих отложений предоставило информации о эрозионных процессах и источниках материала.

Основные выводы данной статьи: тектоническая деятельность и климат изменялись в течение позднего плейстоцена и голоцена, что оказывало влияние на эрозионные и аккумуляционные процессы. Почвенный покров формировался согласно с формированием террас.

Рис. 1. Модель ответного процесса (process-response) гор и горных осыпей холмогорного откоса в Мехиканской котловине и изменения от семиаридных и холодных к влажным и умеренным условиям.

Рис. 2. Дистрибуция типов почвенных профилей на трансекте из гор в низменности.

Рис. 3. Архитиповая катеновая секвенция в направлении из гор в низменности.

Рис. 4. Обобщенная кривая врезания. Крестики на нижней оси обозначают позиции террас, формирующихся в течение коротких перерывов в процессе врезания и прикинутая степень неопределенности возраста террасы означает расстояния под аградационной поверхностью, которая выполняет роль уровня отсчета.

Табл. 1. Выявленный возраст по разным террасям на откосных отложениях в Мехиканской котловине.

Перевод: Л. Правдова