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PLEISTOCENE GEOCRYOGENIC STRUCTURES AT 38°S.L., 60°W. AND 200 M ABOVE SEA LEVEL, GONZALEZ CHAVEZ, BUENOS AIRES PROVINCE, ARGENTINA

Abstract

After reviewing the knowledge on Pleistocene geocryogenic effects in the southern Hemisphere and in Argentina, the authors are presenting two types of Pleistocene Permafrost Geocryogenic effects at 38° S. L., 60°W and 200 m above sea level and under a present mean year temperature of +14.5°C.

The two types of geocryogenic features are: (a) ice wedge casts and (b) gelifluction covers. Ice wedge casts are observed in sandstones, siltstones of upper Paleozoic age and in loess deposits of upper Quaternary age. The gelifluction covers are observed in loess deposits which also contain ice wedge casts; making them a sure geocryogenic evidence. This geocryogenic stage is placed in the upper Pleistocene. This is the northernmost location of fossil ice wedges in the southern Hemisphere. It is also the first report which indicates ice wedge casts filled mainly with calcium carbonate precipitates. This also gives important information for paleoecological; paleo-climatic conditions: after a dry, cold, continental climate stage, with a mean annual temperature of −5°C., −6°C. or lower, in which ice-wedges grew, there was a stage of dry and warmer conditions in which ice wedges melted and calcium carbonate with some sand, silt and clay filled the wedge. Temperature increase, therefore, with respect to present temperature since ice wedge formation is about 20°C.

This temperature increase derived from land evidence is in agreement with research on oceanic cores from the shelf region in the south-western Atlantic.

This rigorous climatic conditions might help to explain certain faunal changes in the upper Quaternary.

Some recommendations are given for an extension and improvement of the present information.

INTRODUCTION

SOUTHERN HEMISPHERE PLEISTOCENE GEOCRYOGENIC PROCESSES

There are few references on fossil melted, ice wedges from the Pleistocene geocryogenic effects in the eastern side of the Andes in Argentina (AUER, 1970; CZAJKA, 1955; CORTE, 1967; LISS, 1969). Most of these ice wedges casts were quite probably produced during the last glacial stage (SUGGATE, 1965); because they are at the surface and can be detected by air inspection or by aero-photographs.

Fossil ice-wedges, developed in greywakes and deformed by solifluxion (gelifluxion) were reported for near Wellington New Zealand at 41°S.L. (TE PUNGA,

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1956) and ascribed for the Riss Glacial Stage. Other periglacial features were reported for New Zealand (COTTON and TE PUNGA, 1955 a, b). In Australia, fossil periglacial slopes formed 31,000—34,000 years B.P. in the last glacial substage (SUGGATE, 1966) and widelly distributed above 1,000 m above sea level and near 37°S.L. (CAINE and JENNINGS, 1968; GALLOWAY, 1970; COSTIN and POLLACH, 1971). Other geocryogenic Pleistocene processes are also described for south Africa and southern Chile.

FOSSIL PLEISTOCENE GEOCRYOGENIC PROCESSES IN ARGENTINA

*Gelifluxion**

The Malvinas Islands (Falkland Islands) stone rivers, became world wide known after DARWIN report (1845). Afterwards these stone rivers gave ANDERSSON (1906) the basic materials for his classical report on solifluction, or soil flow under nival or periglacial conditions. For ANDERSSON and other researchers (CLARK, 1972) the Falkland Islands stone rivers are a Pleistocene geocryogenic event located about 51°S.L. and reaching from a few hundred meters above sea level to below present sea level due to eustatic changes since the last glaciation (CLARK, 1972).

KEIDEL (1913), reported that the filled up valleys in NW Argentina, where glaciation was very weak, were produced by solifluction instead of glacio-fluvial action. These filled up valleys have since glaciation been eroded into beds that are 2,600—3,000 meters deep (AUER, 1970, p. 28).

CALDENIUS (1940), considered that the Patagonian gravel cover or shingle formation (Tehuelche gravel) was dispersed along the Patagonian pediments by solifluction (gelifluction).

CLARK (1972) presented an inventory of fossil periglacial features formed in both Falkland Islands. MARKOV (1969) presented the distribution of the present and fossil periglacial zones of the southern hemisphere; it was indicated that between the boundaries of the present and fossil periglacial zones, contrary to what is indicated in this paper, practically there is no latitudinal differences.

Fossil Ice-Wedges

Frost contraction cracks leading to ice or sand wedges are reported so far for the Patagonian territory in the fossil state. AUER (1970) presented ice wedges casts for southern Patagonia specially south of the 48°L. In a more specialized report CZAJKA (1955), presented pictures of ice wedge casts for Pampa del Castillo, a pla-

* In this report the term *gelifluxion* (or *gelifluction*) is synonym of gelisolifluxion, congelifluxion, and also solifluxion (Am. Geol. Inst., 1972; p. 149); i.e.: The progresive and lateral flow of earth materials under feezing and thawing without discriminating if it happens under permafrost or seasonally frozen ground conditions.

teau 720—750 m elevation, located about 46°S.L. and for San Antonio Oeste at 40°S.L. Also CZAJKA (*Op. cit.*, p. 140), indicated that the northernmost limit of the Pleistocene Permafrost was oriented in a S.W. direction from the south of Mendoza to the mouth of the Río Negro in the Atlantic coast and even more to the north.

More recently LISS (1969) observed the filled-up fissures in the upper Tertiary sediments from Puerto Madryn, 42°30′S.L. implying, with a question mark, its origin as thermal contraction cracking or ice wedges.

The senior author of this paper presented evidences of fossil ice wedges for the Río Gallegos region (CORTE, 1967) and Pampa del Castillo. As it was indicated (CORTE, 1967, p. 17) such shallow ice wedges can be detected from the air or by means of aerial photos. In Table I the up to date information is indicated.

Table I indicates that along the Patagonian plains and from 42°S.L. to the south we can detect ice wedge casts from aerial photos or aerial inspection. According to CZAJKA's photos (1955) it is possible to detect fossil ice wedges as far as 40°S.L.

Table I

Places along Patagonian planes in which fossil ice wedges can be detected from air inspection or by means of aerial photos

In all these locations ice wedges casts are located within a few hundred m above sea level

Place	Reference	Latitude
(1) San Antonio Oeste (Chubut)	CZAJKA, 1955, p. 139	40*
(2) Bajada Colorado (Chubut)	FIGUEROA, A., Plane obs.	42
(3) Pampa del Castillo (Chubut)	CORTE, 1967; CZAJKA, 1955	46*
(4) South Río Deseado (Sta Cruz)	AUER, 1970, p. 29	48
(5) South Río Deseado (Sta Cruz)	FIGUEROA, 1973, Oral inf.	48
(6) E. Lago Cardiel (Sta Cruz)	FIGUEROA, Obs. aerial photos	49
(7) Chalia River (Sta Cruz)	AUER, 1970, p. 28	50
(8) Pediments (cryopediments) between Río Gallegos and Santa Cruz	CORTE, 1973; Obs. from plane	51
(9) South of Río Gallegos	CORTE, 1967	51.30

* Determined from ground inspection not seen from the air.

The present report deals with ice wedge casts developed within the southern boundary of the loess deposits. We can see that the presence of Pleistocene ice wedges within the area of the Argentine Loess deposits, will bring some new refreshing ideas for the interpretation of faunal extinctions, the origin of the loess deposits and other geocryogenic features which so far escaped recognition such as: asymmetrical valleys, pingos, solifluction-(gelifluction)-covers, dells, stratified slope waste deposits, cold climates paleosols. Such features are being studied at the present time and will be object of a special report.

We do not know at the present time if the ice wedges described in this report can be detected from aerial photos or from aerial inspection.

FIELD CONDITIONS

FOSSIL ICE-WEDGES: STRUCTURE AND COMPOSITION

The country rock of the studied area (Fig. 1) is composed of horizontal sandstone and siltstone beds, 20—50 cm in thickness, of upper Paleozoic age. They were correlated by MONTEVERDE (1938) with the "Tunas Formation" of HARRINGTON (1947) of the Southern Sierras of the Buenos Aires Province. The discovery of *Equisetum* fossils by the junior author of this paper (GONZALEZ, M. A.) permits a surer correlation with the "Tunas Formation".

In certain places the flat laying siltstones and sandstones are broken by a system of fissures which were observed in vertical section (Fig. 2) and in plan view

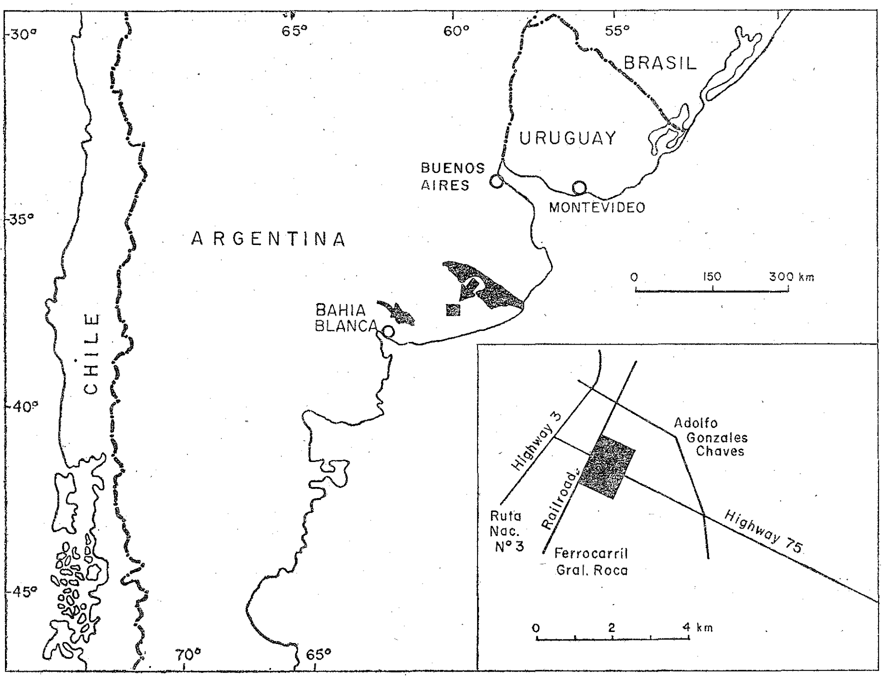

Fig. 1. Location of studied area

(Fig. 3). Along the cracks the bed rocks are displaced by small faults associated with major cracks.

The vertical section shows updomed beds of siltstones and sandstones deeping away from the fissures (Fig. 2) which are whitish due to the accumulation of calçium carbonate. The dip and strike of the layers are clearly indicated in vertical and horizontal sections of the structure (Figs. 1—2). It is to note that MONTEVERDE (1938) when studying these sedimentary rocks as construction materials, indicated the presence of such structures without indicating a cause of the cracking and updoming of the horizontal rock layers.

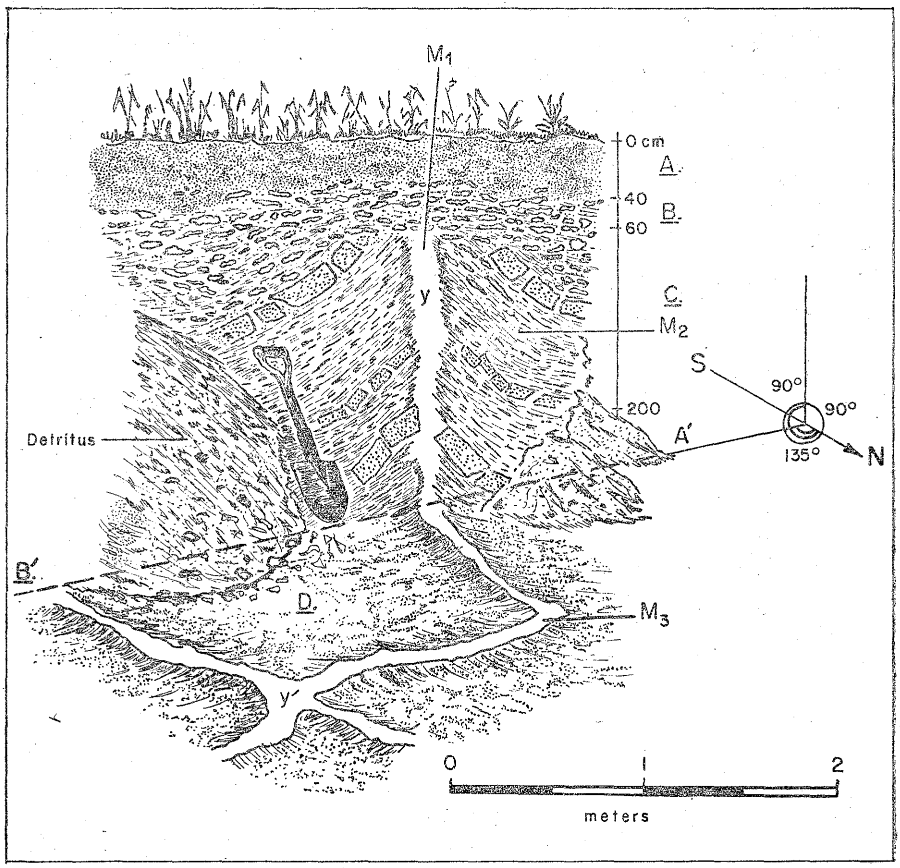

Fig. 2. Inactive or fossil frost contraction fissures (white) cutting horizontal beds of siltstones and sandstones of Upper Paleozoic age (Drawing from a photograph)

The filling of the cracks is made principally of fine fraction and was sampled in several places: M_1 — M_2 — M_3 (Fig. 2). The constituent filling the fissures is calcium carbonate; which in common jargon is called "Tosca" the equivalent of the Mexican and USA "Caliche". The material filling the crack was treated with hydrochloric acid (HCl) in a solution of 10% and was observed that sample M_1 had 77.5°/₀ of calcium carbonate and M_3 75.5% of calcium carbonate. The sample M_2 taken away from the fissure gives only 25.1°/₀ of calcium carbonate. The HCl non soluble part of the sample is composed of broken parts of sandstones, siltstones, quartz with dull surfaces, feldspars and mica. The clay parts were determined by X-ray difractometry giving illite, montmorillonite and kaolinite. Sample M_3 being the deeper one shows more quartz than the other samples.

FOSSIL GELIFLUCTION COVERS (HEAD): STRUCTURE AND COMPOSITION

Other geocryogenic structures observed in the area (Fig. 1) are: congelifluction covers which are affecting the Quaternary sediments mainly loess-like deposits with a crust of calcium carbonate (Tosca) (Fig. 3).

Such gelifluction covers in the loess are deprived in their lower sections of ice wedges (Fig. 3) while in the upper parts, flatter parts, the ice wedges are filled with calcium carbonate; a similar situation like the casts in the sandstones and siltstones (Fig. 2).

Central Argentina Quaternary sediments are generally divided into two parts: Lower or Pampeano (E) and upper or Post-Pampeano (C). The gelifluction covers

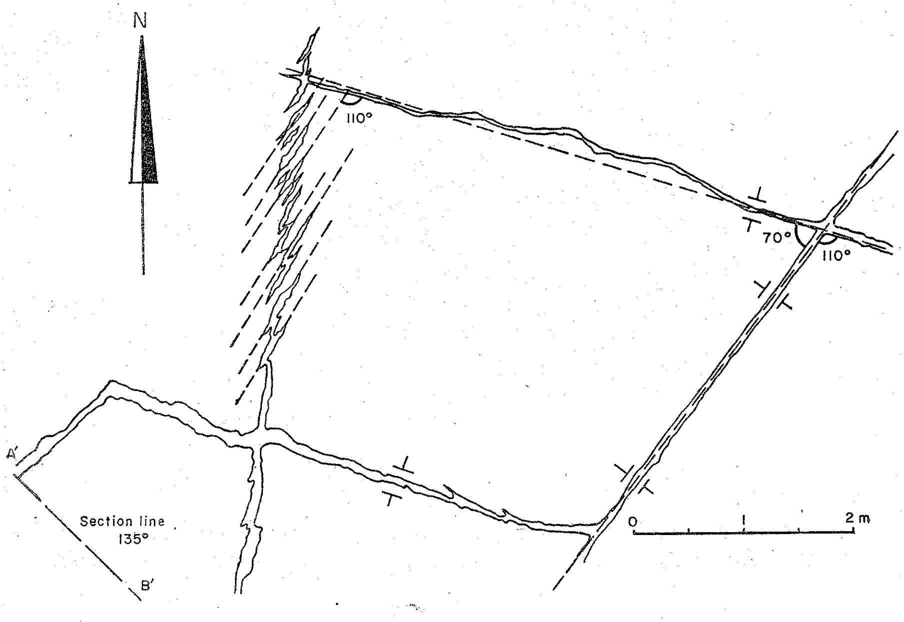

Fig. 3. Plan view of fossil frost-contraction fissures after removing 2 meters of rock cover

Same place as Fig. 2. Drawing from a photograph composed of silts, loam-like materials moved over the silts or loams of the Pampeano (E) (Fig. 4) in an erosion surface (S).

The gelifluction covers are evidenced by various mixed materials, such as:

(a) large blocks up to 1.2 meters from the Pampeano Loams,

(b) pieces of organic soil horizons,

(c) pieces of tosca (calcium carbonate) similar to D in Figure 4.

This broken structure of the sediments are indicating the effects of solifluction which in connection with ice-wedge casts is considered as gelifluction.

DISCUSSION AND INTERPRETATION

FOSSIL ICE WEDGES

According to the information available there is not other geological process besides frost contraction, which is capable of breaking rocks in a polygonal fashion filling them with ice or sediments and afterwards during melting their filling with materials coming from above and the sides of the cracks. The fact that the rocks are upturned in the upper part of the cracks indicates that the amount of contraction is greater at the surface than below; i.e. it is a process associated to temperature of which the changes are greater at the surface than at depth.

Frost contraction of rocks and frozen sediments and materials is produced at the present time in very cold dry environments deprived of snow and ice cover under a mean year temperature of −5°C, −6°C or lower (Leffingwell, 1919; Péwé, 1963) to −17°C (Berg and Black, 1966). In the Russian Arctic it is a very cold climate indicator (Shumskii and Vturin, 1963) and is recognized as such since 1892 according to the works of Figurin.

Frost contraction is also observed in less cold climates like the N.E. USA (Washburn, *et al.*, 1963). However such cracks do not grow yearly and fail to produce a sand or ice wedge. For the active growth of a thermal contraction it is necessary a cold temperature regime in which wedge-shape fissures are filled with ice or sediments. The pressures of contractions and expansions on the filling materials during the cold and warm seasons will produce the upturning of the layers.

The presence of fossil ice wedges in the southern Argentine Pampas under a present year temperature of 14.5°C indicates a temperature change from the time of ice-wedge growth of about 20°C. Boltovskoy (1973, p. 325), based on studies of benthonic and planctonic *Foraminifera* of oceanic waters, which are more stable to temperature changes, indicates temperature decrease of 5°—10°C since Würm for the Atlantic Coasts of S.E. South America.

Temperature increase of 15°C, 16°C or more from the Pleistocene glacial stages to the present in central Europe was determined by Kaiser (1969).

For the case of thermal contraction cracks of Gonzalez Chavez which are filled mainly with calcium carbonate (77.5% and 75.6%) it is indicating that after a dry and cold stage of thermal contraction cracking (mean temperature of −5°C, −6°C) and formation of ice wedges there was a dry warm stage with melting of the ice and precipitation of the calcium carbonate. The precipitation of the calcium carbonate is determined by the acidity of the soils which is a function of the precipitation. Precipitation of calcium carbonate is observed in cold environments such as Northern Greenland, in the tundra of the Rocky Mountains and Alaska and Antarctica.

The greatest accumulation of calcium carbonate in the solum is observed in the warm dry regions of the globe. It is a good question whether or not the great accumulations of calcium carbonate of the dry warm regions like the Argentina Tosca, the American-Mexican Caliche, the Australian Travertine and the Northern Africa and Middle East were formed during the cold dry stages of the Pleistocene.

Among the various features produced by frost the thermal-contraction cracking eading to the formation of ice wedges, soil wedges or sand wedges are the best lold-paleoclimate indicators.

GELIFLUXION

Solifluxion in a wide sense, is not a sure evidence for past cold climatic conditions unless it is associated with other safer geocryogenic indicators such as: ice wedges, pingos etc.

In the present case in question the solifluxion features are (Fig. 4) merging into ice wedge casts filled with calcium carbonate in the upper parts of the slopes; consequently they are gelifluxion processes. In the slopes the soil motion have destroyed all evidences of frost action. The inclusion of pieces of organic soil materials indicates a rapid motion of surface materials which are incorporating them into the lower part of the moving layer.

The fact that we are observing ice wedge casts in this part of the country is indicating that we should look for other geocryogenic or periglacial features which confirms the whole cold climatic facies like: (1) Pingos, (2) Thermokarst features, (3) Asymmetric valleys, (4) Gelifluxion covers and lobes, (5) Stratified slope waste deposits, (6) Loess, (7) Cold climate paleosols. We are inventoring all these evidences in this part of the country and they will be the object of special reports.

CONCLUSIONS AND RECOMMENDATIONS

(1) Two types of Pleistocene Geocryogenic features are presented:

(a) Ice wedge casts filled mainly with calcium carbonate; produced in Upper Paleozoic sandstones and siltstones and in upper Quaternary loess covers;

(b) Gelifluxion covers in loess which in the upper parts of the slopes shows ice wedge casts filled also with calcium carbonate.

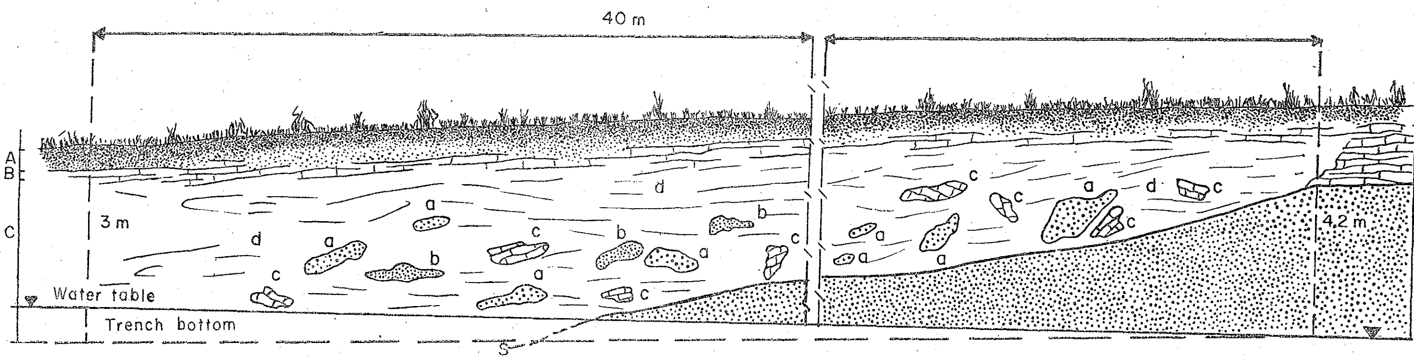

Fig. 4. Inactive fossil gelifluction covers „C" of Upper Quaternary, moving over a surface „S" of Pampeano loess – Lower or Middle Quaternary

The gelifluted layer is composed of: (a) blocks up to 1.2 m of Pampeano loess; (b) pieces of black soil; (c) calcium carbonate blocks – tosca – similar to „D"; (d) matrix of loessial material

(2) The exact time in which these geocryogenic events were produced is not surely known since we do not have absolute dating. However, as work is progressing it is observed that fossil snails in the wedges and in the gelifluxion covers, are related to the last glacial stage, Upper Pleistocene events.

(3) The present mean year temperature of this area located at 38°S.L., 60°W and 200 m above sea level is about +14.5°C. Considering that for ice wedges to grow it is necessary a climate with a mean year temperature colder than −5°C, −6°C we should infer an increase in the mean temperature of about 20°C since ice wedges stopped growing at the last glacial stage. A corresponding temperature increase of 15°C or more were determined since the last glacial stage in Central Europe (Kaiser, 1969).

(4) The importance of this finding of permafrost evidence in the Upper Quaternary loess in South America will bring some new light into the origin of the Argentine loess and also for explaining faunal extinctions.

(5) It is recommended:

(a) to look for other geocryogenic evidence in the area and farther northward,

(b) to ascertain whether or not other glacial and interglacial stages have left their cryogenic imprint in the geological record,

(c) to make a study of the faunal assemblages of the cryogenic stages (glacial) and their relation with the intercryogenic (interglacial) stages of the Quaternary,

(d) to make a complete inventory of the Argentine solifluction references — present and Quaternary.

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