Geomorphology and Paleoecology of the Arid Diagonal in Southern South America

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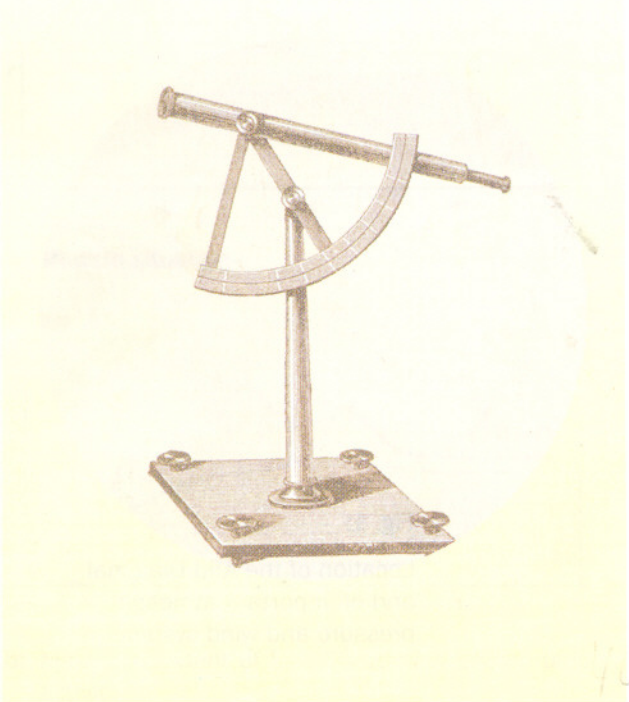
ABSTRACT

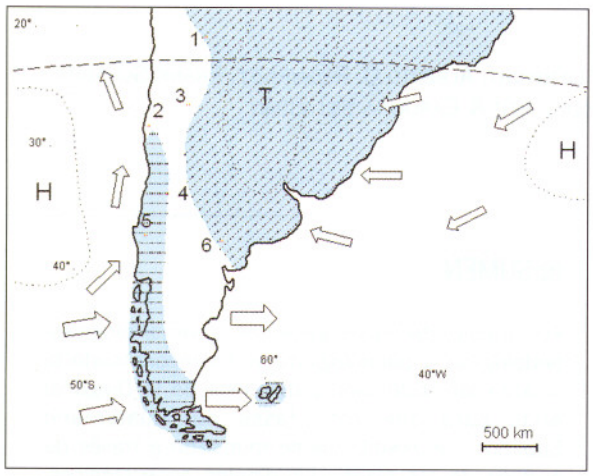
Position, extent and intensity of the Arid Diagonal at various time slices during the upper Quaternary were reconstructed. Geomorphic, pedologic and palynologic evidences indicate significant shifts of the geoecological belts with regard to altitude and extent. In this paper these are shown as N–S–transects, as elevation/time graphs of various paleoclimatic indicators and as maps. The latter give an idea of the extent and the moisture conditions of the Arid Diagonal, as well as of the patterns of modern and past atmospheric circulation.

RESUMEN

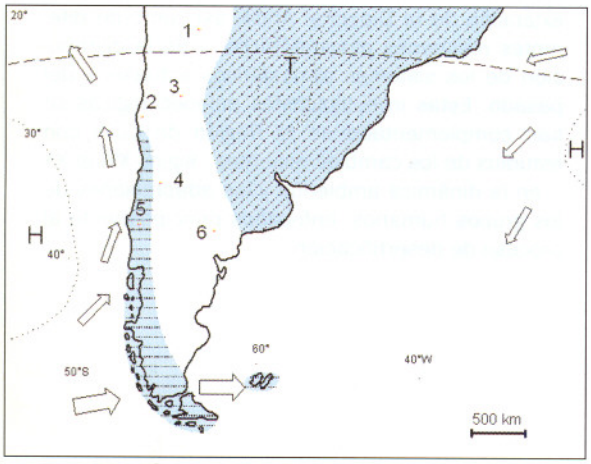
Por medio de investigaciones geomorfológicas, pedológicas y palinológicas se ha reconstruido la localización, extensión y dinámica de la Diagonal Árida para diferentes fases del Cuaternario Superior. Los resultados se muestran a través de perfiles de los pisos altitudinales geoecológicos, por diagramas de variación, tanto temporal como espacial de diferentes indicadores y parámetros paleoclimáticos, y por bosquejos cartográficos de la extensión de la Diagonal Árida, así como de diferentes regímenes pluviométricos, y de la distribución de los sistemas atmosféricos actuales y del pasado. Estas investigaciones paleoecológicas se han complementado en la Región de Cuyo con estudios de los cambios recientes - siglos XVI al XX – en la dinámica ambiental y las adaptaciones de los grupos humanos, enfocados principalmente al proceso de desertificación.



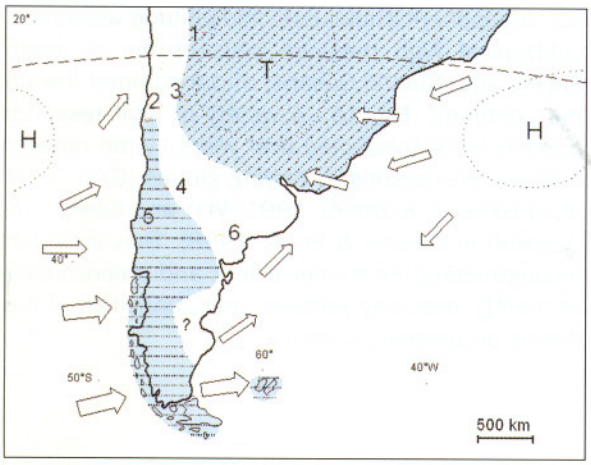
■ The South American Arid Diagonal (AD) is located at the interface between several elements of the atmospheric circulation: mid-latitude westerlies, subtropical high pressure cells of the southern Pacific and Atlantic Oceans, and a summer low on the continent (Fig. 1a). A variety of joint research projects were conducted over years by the present authors co-operating in varying groups (GARLEFF et al. in GARLEFF & STINGL 1991; VEIT and SCHÄBITZ & LIEBRICHT in GARLEFF & STINGL 1998). They aimed at reconstructing the former extent and paleoclimate of the AD, including patterns and intensities of the driving air pressure systems.



a: Modern situation



b: Situation at about 6 – 7 ka BP



c: Situation at about 12 – 13 ka BP

Prevailing summer precipitation

Prevailing winter precipitation

Research-areas 1-6,
compare Fig. 3a to 3f

Arrows = Wind direction
(different intensities)

Fig. 1:

Location of the Arid Diagonal and of important atmospheric pressure and wind systems.

As paleoclimatic indicators were used in particular:

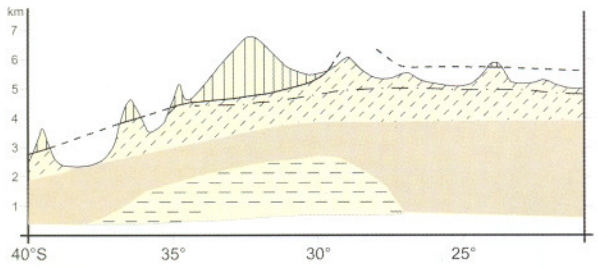
(1) Climate-related landforms and deposits, especially of glacial and periglacial origin, which indicate activity of the geomorphic systems.

For example, the extent of moraines allows for reconstructing glacial advances related to cooler and/or moister conditions (ZIPPRICH et al. in STINGL & PETEREK 1998). The distribution of relic compared to modern permafrost-related landforms, such as smoothed slopes ("Glatthänge"), indicates periglacial episodes (Fig. 4 and GARLEFF & STINGL 1996). Planation surfaces provide evidence of paleoclimatic trends; pediments were formed under a warm arid to semi-arid climate, and cryopediments are indicative of cold arid to semi-arid environments. Further geomorphic indicators were eolian deposits and landforms (REICHERT et al. in GARLEFF & STINGL 1998).

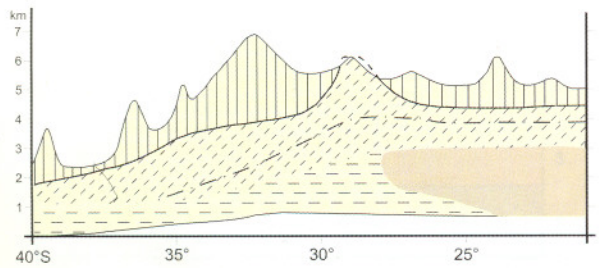
(2) Paleosols and organic sediments, which indicate surface stability.

These were studied pedologically and palynologically respectively, and in cases radiometrically dated. They provide an age framework and information on the paleoecologic conditions of their formation (VEIT and SCHÄBITZ & LIEBRICHT in GARLEFF & STINGL 1998).

One important result is that significant shifts of the altitudinal belts of geomorphic activity occurred along the Argentine Andes from Late Pleistocene to modern times (Fig. 2). Six study areas, providing detailed resolution of paleoclimate indicators through elevation and time, demonstrate that geomorphic activities changed their distribution patterns significantly at times (Fig. 3). Among others, such shifts had great impact on the evolution of the regional vegetation cover, in particular on the location of plant refuges during phases of environmental poverty (ARMESTO et al. 1996, VILLAGRAN et al. in GARLEFF & STINGL 1998).



a: Modern situation



b: Maximum extent of late Quaternary geomorphic activity

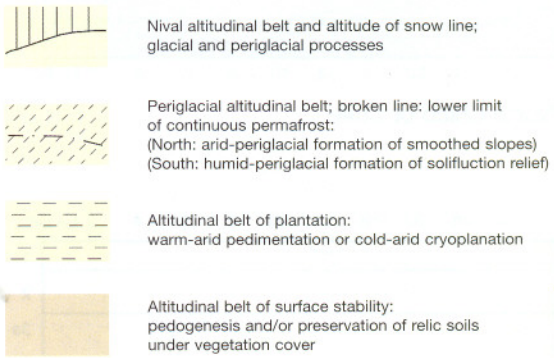
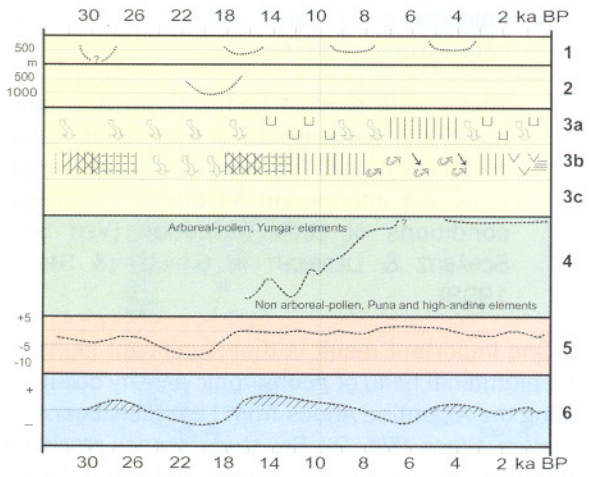
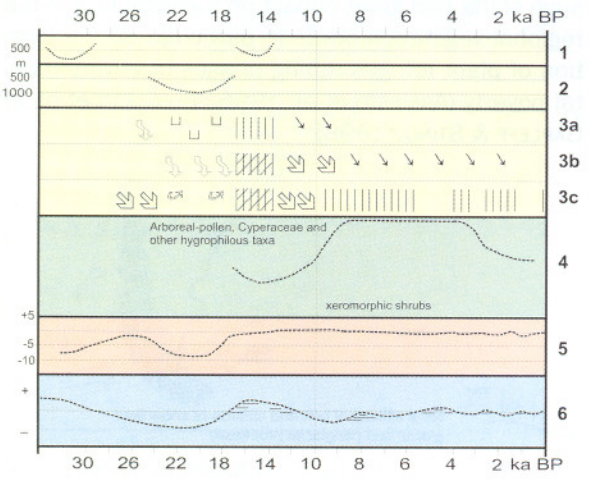


Fig. 2:

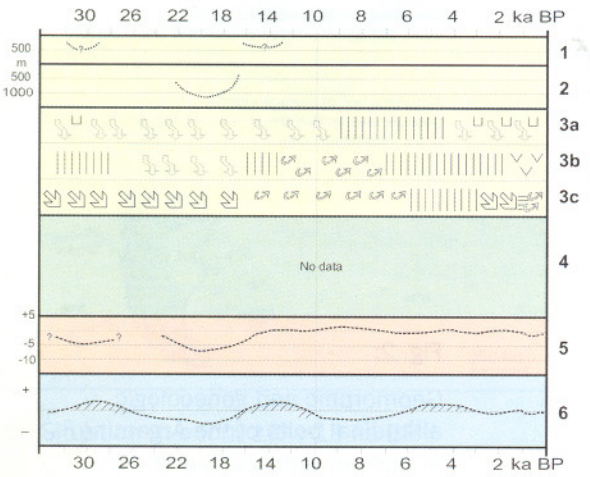
Geomorphic and geoecologic altitudinal belts of the Argentine Andes between 22°S and 40°S.



a: Argentine Puna and Cordillera Oriental



b: Norte Chico of Chile



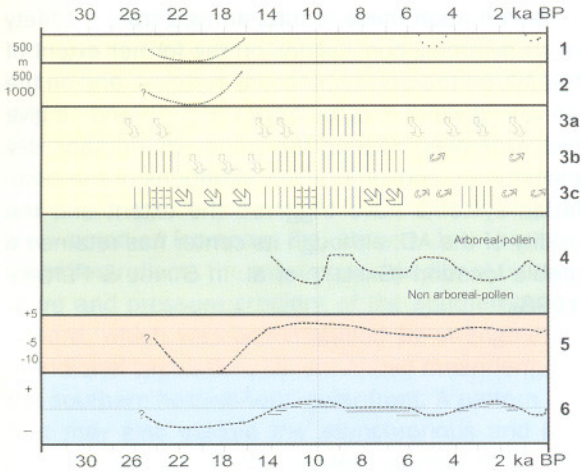
c: Sierra de Famatina – Valle de Abaucán

Morphodynamics
- Gelisolifluction and periglacial denudation
- Rock glacier activity
- Dry creep
- Sheet erosion, pedimentation
- Valley-deepening
- Valley-filling
- Eolian processes

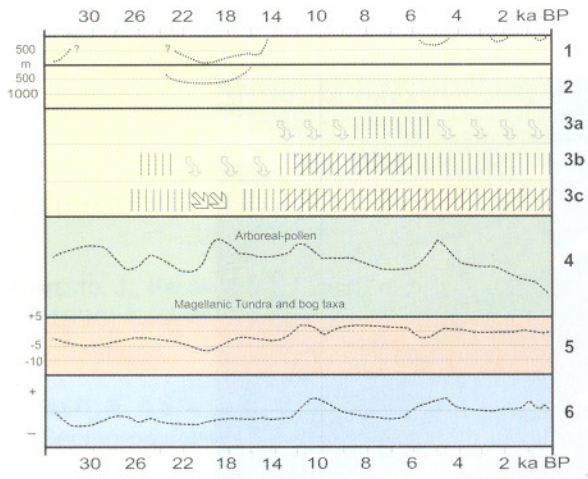
Pedogenesis
- Stable surface with pedogenesis
- Formation of argillic horizons
- Rubefication
- Formation of carbonate-enriched horizons

Precipitation
- Prevailing winter precipitation (westerlies)
- Prevailing summer precipitation (monsoonal system)

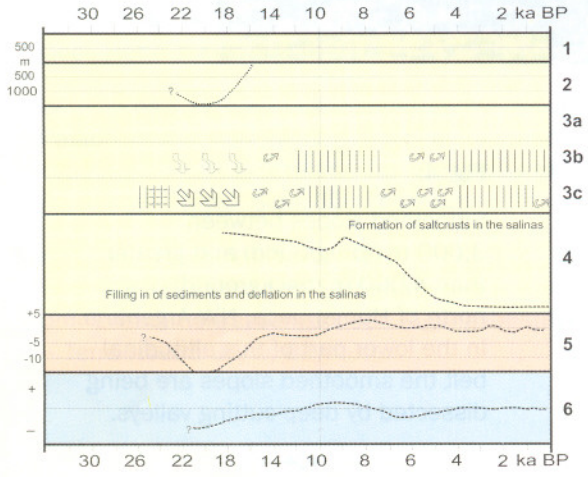
1. Depression of snow line
2. Depression of the belt of active permafrost, accompanied by the enlargement of smoothed slopes
3. Morphodynamics and pedogenesis
   a) Alpine belt
   b) Montane belt
   c) Colline belt
4. Vegetation/palynology, sedimentology of closed basins
5. Temperature deviation from modern level
6. Precipitation deviation from modern level



d: South-Cuyo — Northwestern-Patagonia



e: South Central Chile



f: Northeastern Patagonia — Southern Pampa

Fig. 3:

Landscape and climate evolution derived from geomorphic, pedologic and paleoecologic evidence.

The late Quaternary maximum extent of glaciers was not synchronous within and outside the AD. Southwest of the AD, in the humid Andes of Patagonia, it occurred around the global last glacial maximum, whereas in dry areas such as the Norte Chico of Chile or the Andes of northwestern Argentina, the glacial maximum was not reached before the late glacial. This asynchronous depression of the snow line is mainly explained by different moisture supply. On the other hand, the depression of the lower limit of permafrost is primarily controlled by temperature. Thus, the observed dissimilar depressions of the lower limits of glaciers and of permafrost (regarding space as well as time, Fig. 3) reflect regional variations in precipitation, whereas the shifts in temperature occurred approximately simultaneously throughout the area.

Based upon these results derived from a variety of study areas, conclusions on the former extent of the AD, on the driving pressure systems, and on the prevailing winds may be drawn (Fig. 1b and 1c give two examples). During the upper Quaternary, displacements and/or intensity variations of the circulation systems have triggered the extent and the aridity of the AD, although its center has retained a stable location (GARLEFF et al. in STINGL & PETEREK 1998).

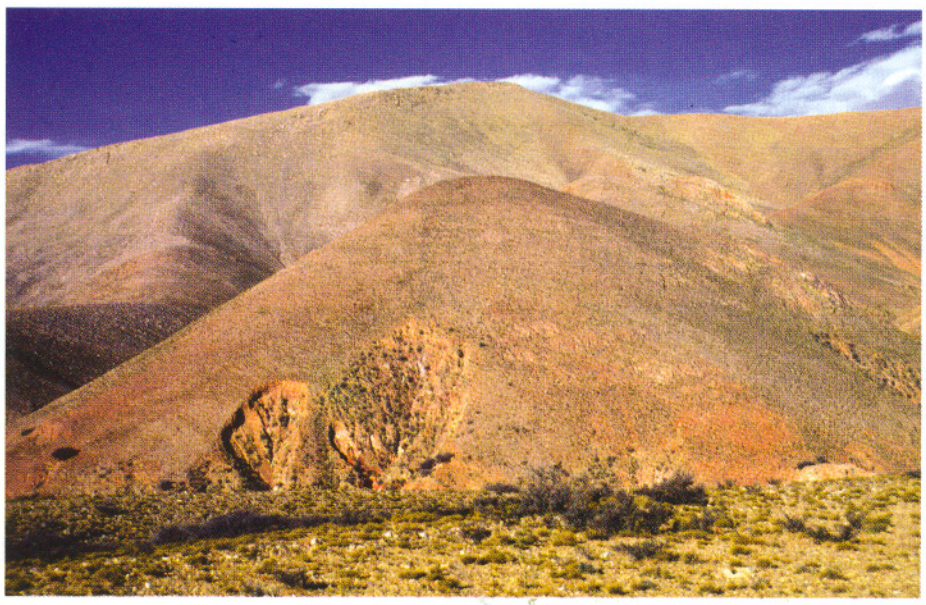


Fig. 4:

Smoothed slopes between 3,000 m (foreground) and greater than 4,000 m (background) a. s. l. north of Humahuaca, NW-Argentina. In the lower part of this altitudinal belt the smoothed slopes are being dissected by deep-cutting valleys.

The following mutual relationships between changes in extent and intensity of the AD and in the circulation patterns are proposed: The humid late glacial phase at the northeastern flank of the AD indicates intensification and extension of the monsoonal system compared to the present, whereas there was no contemporaneous major change in the westerlies (compare Fig. 1a with 1c). This constellation reflects the maximum meridional temperature and pressure gradient of the southern hemisphere, which was accompanied by strengthened meridional circulation, i.e. enhanced meandering of the southern hemispheric polar front. A pattern like that may also explain the asynchronous arid and humid episodes of the eastern compared to the western section of the AD. Contrasting to this, the circulation pattern of the early to middle Holocene phase of aridification correlates to weaker gradients of air pressure and temperature (Fig. 1b) reducing the exchange of air masses, i.e. of moisture.

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