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SHORT NOTE

Tectonic wedge geometry at Bardas Blancas, southern Andes (36°S), Argentina

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Abstract—A tectonic wedge at the mountain front of the Cordillera Principal, Mendoza province, Argentina, shows some geometrical features that depart from examples described elsewhere. This wedge underthrusts the roof sequence beneath a blind thrust. The wedge is deformed by imbricate backthrusting that branches into the hangingwall ramp of the leading horse. This backthrust system contributed to the uplift and shortening of the mountain front. © 1997 Elsevier Science Ltd.

INTRODUCTION

The mountain front of the Principal Cordillera, southern Andes, has an uncommon structural geometry, which is identified as a new geometry for the termination of a blind horse forming a wedge beneath a roof sequence. A series of backthrusts sprouts from the leading branch line at the hangingwall ramp and mainly displaces segments of the wedge rather than the roof sequence. The purpose of this paper is to introduce this newly identified geometry and to describe its development.

GEOLOGICAL SETTING

The study area, located at 36°S latitude, near Bardas Blancas, Mendoza province, Argentina, is part of the southern sector of the Cordillera Principal, which locally forms the eastern foothills of the Andes (Fig. 1a). The oldest rocks that crop out are a suite of Permo-Triassic volcanic rocks, the Choiyoi group, whose base is unexposed in this region. They are rhyolitic–dacitic rocks with some intercalated clastics, and are overlain by a Mesozoic sequence composed of marine sedimentary rocks and continental units (Fig. 1b, c). Tertiary molasse sequences cover the Mesozoic strata to the east of Bardas Blancas. Laccolithic and sill-like Tertiary intrusives, as well as extrusive units, are widespread along the length of the mountain front (Groeber, 1980). The tectonic configuration was attained mainly in the middle to upper Miocene during the Andean orogenic cycle (for a synthesis, see Ramos, 1988).

STRUCTURES

The main folds and faults of the area are shown in Fig. 1(c). The magnitude of the largest folds reaches about 900 m half-wavelength, and the folds are parallel flexural-slip folds. Thrusts form imbricate and duplex systems with individual displacements ranging from several tens to a few hundred meters. Fault-bend folds related to staircase-trajectory thrusts occur stratigraphically above a huge gypsum horizon, the Jurassic Auquilco Formation (Fig. 1b). Examples are the Barrosa and Barroso anticlines (Figs 1c & 2 section P–P′). Fault-propagation folds are associated with an imbricate system of backthrusts, in the oldest exposed rocks include the Llano Grande, Ventana and Potimalal anticlines (Figs 1c & 2 section P–P′). The overall trend of the structures is roughly north–south. The thrusts verge both east and west (Figs 1c & 2 section P–P′).

The uplift of the mountain front in this area is attributed to the emplacement of the blind Bardas Blancas thrust, which probably cuts across unexposed Paleozoic sequences (Horqueta and Imperial Formations according to Gorroño *et al.*, 1984) and roots into Precambrian metamorphic rocks (Fig. 2). Basement-derived blind thrusts for the mountain front are supported by seismic and drill hole data (Kozlowski *et al.*, 1993; Mingramm *et al.*, 1993; Manceda and Figueroa, 1995). These faults appear to cut up sequence until they reach the Auquilco gypsum, and then form a flat and propagate detaching the strata above this horizon. Whether these thrusts branch at depth to a common décollement or propagate down with a slightly decreasing dip to the west is uncertain. The height difference between the structural level of the Choiyoi Group across the

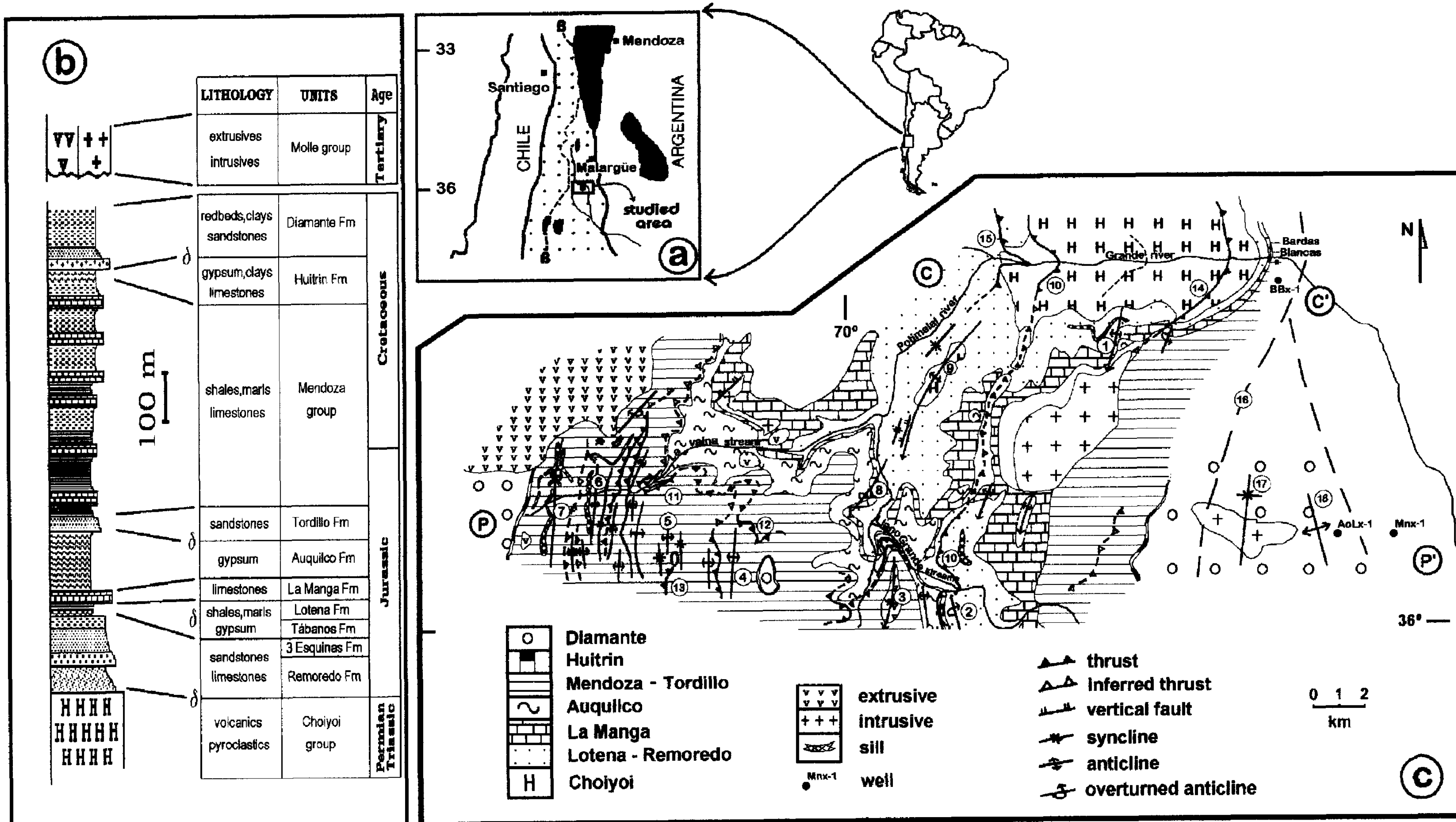

Fig. 1. Geology of the Bardas Blancas area. (a) Location of the study area: Cordillera Principal thrust and fold belt-stippled, basement outcrops (mostly Palaeozoic)—dark areas. (b) Stratigraphic column. δ: unconformity. (c) Geologic map of the study area. P–P′, C–C′: cross-sections of Fig. 2. Numbers 1–18: location of main structures. 1: Palao-Mahuida anticline, 2: Llano Grande anticline, 3: Cerro Vulcanita syncline, 4: Cerro Barrosa anticline, 5: Cerro Barroso anticline, 6: La Refaloza anticline, 7: Lagunas Turbias anticline, 8: Potimalal anticline, 9: Ventana anticline, 10: Llano Grande backthrust, 11: La Vaina thrust system, 12: Cerro Barrosa thrust, 13: Cerro Barroso thrust, 14: Rio Grande backthrust, 15: Pellin backthrust, 16: Bardas Blancas blind thrust, approximate trace of leading branch line, 17: Lagunitas syncline, 18: Lululén anticline.

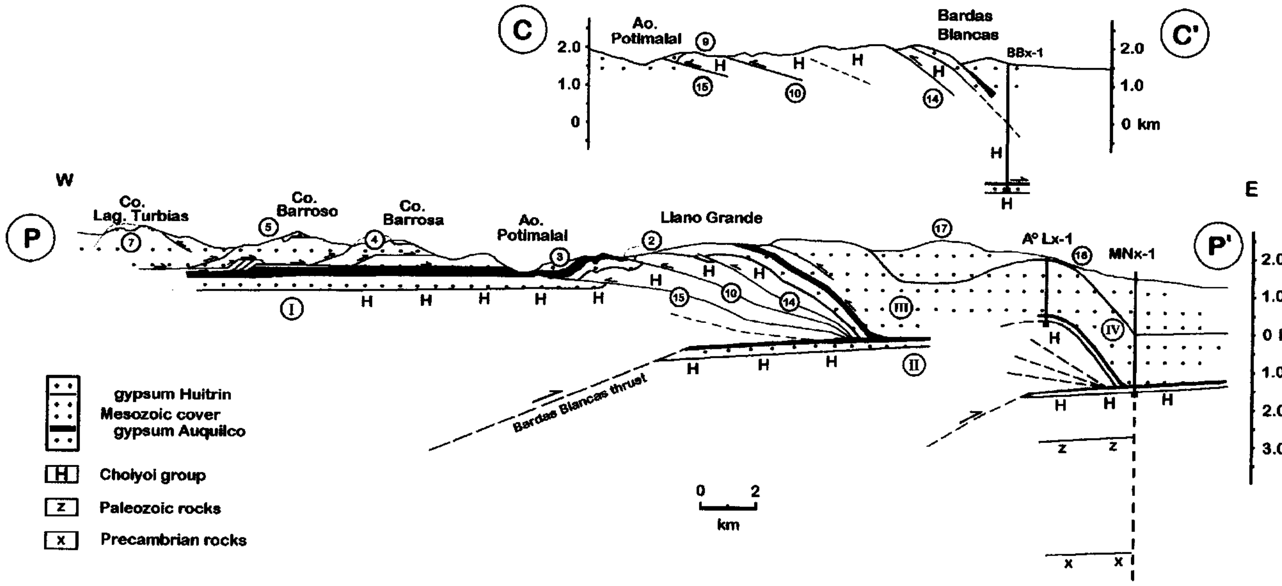

Fig. 2. General cross-sections. The eastern ends of the sections C–C′ and P–P′ were constructed with the aid of data from Groeber (1980); Baldi *et al.* (1984); Manceda *et al.* (1992) and three YPF S.A. wells: Arroyo Lululén x-1 (A°Lx-1), Malal Negro x-1 (MNx-1) and Bardas Blancas x-1 (BBx-1). Numbers in structures correspond to Fig. 1(c). Points I and II: see text. The structure of the Mesozoic sequence is very simplified at points III and IV. Tertiary sills and laccoliths are not shown. The thicknesses of the Paleozoic sequence and the Precambrian metamorphics were inferred from nearby areas following Gorroño *et al.* (1984).

Bardas Blancas thrust (points I and II of Fig. 2) precludes the interpretation of a linked décollement beneath the area, and supports the latter hypothesis (Dimieri and Nullo, 1993).

The abundance of backthrusting in this mountain front is noteworthy, particularly because these faults are almost the only ones found within the basement outcrops. For instance, in the Río Grande valley, the outcrops of the Choiyoi group (Fig. 1c), i.e. the hangingwall of the Bardas Blancas major blind thrust, contain at least three backthrusts with decreasing dips to the hinterland (Fig. 2, section C–C′). These backthrusts are interpreted to branch from the deeper Bardas Blancas blind thrust and form an imbricate system within the wedge.

When this geometry is compared to other mountain fronts where blind thrusts are prevalent (Morley, 1986; Vann *et al.*, 1986), the location of these backthrusts within the leading blind horse is quite different. In other mountain fronts with backthrusts, the deformation is in the roof sequence with either a frontal triangle zone (Jones, 1982) or a passive roof duplex (Banks and Warburton, 1986). As with the triangle zone and passive roof duplex, the blind horses at Bardas Blancas exploit a weak horizon for a roof thrust. Still, the deformation due to emplacement of the major blind thrust is concentrated in the wedge and not the roof sequence.

STRUCTURAL EVOLUTION

The tectonic wedge at Bardas Blancas, which comprises mainly basement rock of the Choiyoi Group, was emplaced by blind thrusting that steps up to the Auquilco Formation (gypsum) causing delamination of the roof sequence above this horizon. The wedge is interpreted to have become pinned, possibly due to structural stacking in the roof sequence at the wedge front, and also due to overburden growth by synchronous Tertiary molasse deposition in the adjacent basin on the east side of Bardas Blancas. The backthrusts in the wedge are interpreted to have formed when it pinned.

Figure 3 shows a sequential deformation of a pinned wedge by backthrusts which is area and line balanced. Folded faults are depicted with kink geometry for simplicity. The sequence of backthrusting occurs in a piggyback fashion towards the hinterland. This system sprouts out at the leading branch line of the hangingwall ramp. This interpretation indicates the importance of backthrusting when studying the structural evolution of mountain fronts formed by basement-driven blind thrusting.

CONCLUSIONS

When the leading horse of a tectonic wedge delaminates along a favourable horizon, in some models (Charlesworth and Gagnon, 1985; Banks and Warburton, 1986; Dunne and Ferrill, 1988), the delaminated sequence is deformed by imbricate thrust systems, whereas the leading wedging horse itself remains internally unfaulted. Other proposed geometries involve a foreland-propagating duplex thrust systems within the

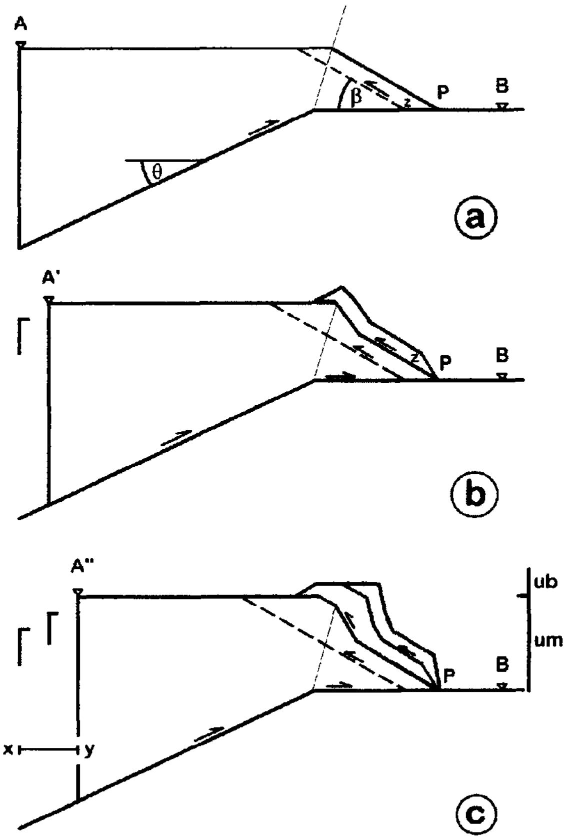

Fig. 3. Sequential evolution of a pinned tectonic wedge. (a) A,B, Z: reference points. P: pinned branch line. θ: main thrust dip angle. β: initial backthrusts angle. The dashed line indicates the position of the future backthrust. (b) The advancing wedge is itself backthrusted from the hangingwall ramp. (c) ub: uplift due to backthrusting. um: uplift due to main blind thrusting. Horizontal distance x–y is shortening accommodated by imbricate backthrusting.

wedge block (Jones, 1982; Morley, 1986; Vann *et al.*, 1986). The structures seen in the Bardas Blancas profile indicate that the wedge's leading horse has a geometry defined by a system of imbricate backthrusts propagating towards the hinterland.

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