STRUCTURAL STYLES IN THE DOMEYKO RANGE, NORTHERN CHILE

Susie M^c^ELDERRY[1], Guillermo CHONG DIAZ[2],
David J. PRIOR[1] and Stephen S. FLINT[1]

(1) Department of Earth Sciences, University of Liverpool, P O Box 147, Liverpool L69 3BX, UK.
(2) Departamento de Geología, Universidad Católica del Norte, Antofagasta, CHILE.

KEY WORDS: Domeyko fault system, strike slip faults, thrust faults, kinematics

INTRODUCTION

In the North of Chile, the Domeyko Range forms the Precordillera of the Andes, situated between Longitudinal Valley and the Western Cordillera. The Domeyko Fault System, otherwise known as the West Fissure Fault System, is located within the Domeyko Range (Figure 1). The fault system is known to extend for some 800km, from 21°S to 28°S. It can be divided into segments, based on the fault patterns and continuity. In between each segment is an area of non exposure (Mpodozis et al 1993). The northernmost segment extends 200km from Quebrada Blanca to Chuquicamata. Immediately to the south, from Chuquicamata to Limon Verde, the Calama Basin hides any exposure of the Domeyko Fault system. The central fault segment passes 300km from Limon Verde to Vaquillas and is limited to the south by 50km of non- exposure. The southern segment is about 200 km long and begins near El Salvador passing to Quebrada Carrizalillo. Considerable effort has been expended in the analysis of satellite imagery. As such, the traces of major structures are well known. All three accessible segments have been mapped and to some extent three dimensional geometric models have been developed. Kinematic analyses of these fault systems are rather rarer. Very detailed kinematic studies have been completed in particular mines but there are few data across more extensive regions of the Domeyko Fault system. This paper presents preliminary kinematic data from the southern portion of the central segment of the Domeyko Fault system and outlines some of the problems associated with collecting such data from the Domeyko region.

Faulting activity in the Andes, broadly corresponds temporally and spatially with the activity of the magmatic arc. Faulting is thought to relate to the emplacement of the porphyry bodies in the Eocene (Coira et al 1982, Scheuber et al 1994). The present high Cordillera has not always been the site of the magmatic arc. The locus of the magmatic arc in the Latest Cretaceous to Oligocene corresponded to today's Precordillera. It is believed that hot fluids in the crust, corresponding to the magmatic arc, raise crustal temperatures and pore-fluid pressures. These factors contribute to a weakening of the crust at the site of the arc. As the magmatic arc migrated east over time, so the deformation centres (generally fault systems) have also migrated east over the same time. The age of individual faults and the relationships between individual faults however remains obscure.

STRUCTURE OF THE DOMEYKO RANGE

The structure of the Domeyko range is characterised by a core Palaeozoic rocks, mainly intrusives, flanked with igneous extrusives and volcanogenic sediments thought to be of Triassic age (Chong, 1973), some Triassic reefal sediments, Jurassic marine rocks and Cretaceous continental clastics.

There are later Tertiary sediments and ignimbrites further away from the range. The contacts between the core, Triassic and Jurassic and younger units are mainly tectonic, commonly thrusts (as exemplified by La Escondida fault). Typically at any latitude in a section across the Precordillera, the faults comprise one major strike slip fault and smaller thrust faults or vice versa (Tomlinson et al, 1993). The structure of this hill range has been interpreted as both an anticline (Reutter et al , in press) and a positive flower structure(Mpodozis et al, 1993).

The Domeyko Fault system was active during the Incaic tectonic event (Reutter et al., in press: Maksaev, 1990: Dobel et al, 1992) and the emplacement of the main copper porphyries is dated in the same time period. The fault system is interpreted to have accommodated a transpressional regime (cf. Sanderson and Marchini, 1981). Work carried out by Maksaev suggests a dextral sense to the main faults, whilst work by Reutter et al suggests a dextral sense for the system until 33Ma, when, after a change in the orientation of active faults from north south to NE-SW and back again, the sense changed to sinistral. This is based upon textural studies in altered rocks in the Chuquicamata region. The faulting has been interpreted as responding to the transmitted stresses from the subduction interface. From the relative plate motion vectors (Pardo-Casas and Molnar, 1987) this would lead to an expectation of a dextral sense from 49-35 Ma, followed by a more compressive phase until 26Ma then later sinistral compressive stresses.

In the southern portion of the central fault segment the main strike slip fault is the Sierra de Varas (SdV) fault. Abutting this are the Profeta thrust and the La Escondida fault. This study concerns the area to the south of the intersection of the SdV fault and the Profeta thrust (figure 1). Immediately to the north, the La Escondida fault and the SdV fault define a shear lozenge (Mpodozis et al, 1993b). The area of study may be the northern part of a similar lozenge. Here, the SdV fault provides the eastern limit of the fault system. The limit of the fault system in the west is a reverse fault juxtaposing Jurassic and Tertiary units in contact.

Passing from west to east, across the system, the first evidence of deformation is the fault bounding the Jurassic units. The fault dips to the east. In the north of the study area the fault is shallow, carrying Jurassic calcareous siltstones over poorly lithified Tertiary conglomerates. In Quebrada Profeta, also in the north of the study area, this fault occurs along an evaporite horizon of varying width, generally of the order of 10's of metres. In Quebrada Las Mulas, further to the south, the fault occurs over a much smaller width (~5m), cutting through an intrusive ignimbrite. The fault emplaces Jurassic rocks against younger Tertiary units to the west. The fault plane is sub-vertical with very well developed, mainly down dip slickenlines. The slickenlines are contained in seams of a few mm thickness comprising a fine grained, dark coloured material.. Profile views of many of these seams show offsets. Across approximately 5 metres perpendicular to the fault, these seams form a complex network. Cross cutting relationships indicate a complex local deformation history involving rather more than the simple down-dip movements. The mechanism of deformation here is clearly different to that in the evaporites, presumably a result of the presence of the ignimbrite with a different rheology and possibly higher temperature of deformation. These seams provide some of the freshest fault rock material from the Domeyko range and detailed laboratory investigations will be completed to constrain better the local kinematic history and the conditions of deformation.

Passing into the Jurassic marine rocks to the east, there are a variety of deformation structures. There are folds on 10's metres scale throughout the Jurassic and small scale faults. The folds have hinge lines orientated NE-SW, with shallow plunges. In the north of the area, there is a substantial evaporite horizon (Oxfordian - Kimmeridgian) which has folded in a complex manner. This evaporitic material is contained within a fault bound wedge which dies out to the south. The hinge lines of folds lie sub parallel to the Profeta thrust to the east suggesting that the folding and this structure may be related.

The Jurassic is limited to the east by the Profeta thrust. Interactions with topography clearly show that this dips shallowly to the east. The Profeta thrust emplaces andesites, probably of Triassic age, above the Jurassic marine rocks. No outcrop scale kinematic indicators have been observed associated with the Profeta thrust.

In Quebrada Las Mulas, at the south of the studied area, andesites, probably of Triassic age, have been mapped in detail, at scales of 1:500, in an attempt to unravel the structural history. The andesites exhibit primary structures such as flow banding and are cut by a series of breccia bands, of 2-20cm thickness. The significance of these breccia bands is somewhat ambiguous. The primary fabrics form a cluster when plotted as poles on a stereonet. The breccia bands at the eastern margin have a single intersection. Further west however the breccia bands have a seemingly random distribution. It is uncertain whether they represent some tectonic disturbance. If treated as Andersonian structures the intersection may represent the intermediate stress axis. Alternatively the breccias may be depositional, possibly forming around "tongues" of andesite as it flowed. To resolve this, sample analysis and geometrical modeling are being undertaken.

To the east the SdV fault is poorly exposed. It is assumed to be vertical, from its interaction with topography, and is covered by a lower Miocene ignimbrite which it offsets with a dextral sense by a few 10's of metres (Mpodozis et al, 1993b).

OUTSTANDING PROBLEMS

The different lithostratigraphic units of the Domeyko Range have responded differently to the deformation associated with the Domeyko fault system. Kinematic information is slight, but it is clear that there are variations in kinematics and kinematic histories on several scales. It is clear that different lithologies will have had different rheologies and will have responded differently in deformation. This is particularly important if there were significant thermal differences, such as those generated by intrusions concomitant with deformation. However, at this stage, it is not clear how much of the differences in deformation style and kinematics can be attributed to partitioning in a single deformation episode as opposed to the superposition of discrete events with different kinematics and perhaps at different conditions.

One practical problem is in obtaining good kinematic information from desert exposures. Whilst lack of vegetation is a clear advantage for remote sensing and large scale mapping it is a hindrance to detailed kinematic analyses. Good exposures are rare, especially in the case of important contacts. Where exposure is observed one has to fairly pervasive fracturing related to very recent tectonics, unroofing and weathering.

In order to add as much detailed information as possible about the chronology, absolute timing, sense and conditions of deformation, further work is being carried out on numerous samples. Dating, stable isotope work (to identify source and mobilisation of fluids), microstructural analysis (to identify deformation mechanisms and senses of movement) and geometrical modeling are all being undertaken.

REFERENCES

Chong, G. 1973, Reconocimiento geológico del area Catalina, Sierra de Varas y estratigrafía del Jurásico del Profeta. Memoria, Universidad de Chile, Fac Ciencias Fis. y Mat.

Coira B., Davidson J., Mpodozis C. & Ramos V. 1982. Tectonic and Magmatic evolution of the Andes of North Argentina and Chile. Earth Science Reviews , 18, 303-332.

Dobel R., Friedrichsen H., & Hammerschmidt K. 1992. Implication of Ar/Ar dating of early Tertiary volcanic rocks from the north Chilean Precordillera. Tectonophysics, 202 55-81.

Maksaev V. 1990. Metallogeny, geological evolution and thermochronology of the Chilean Andes between latitudes 21° & 26° south and the origin of major porphyry copper deposits. PhD thesis, Dalhousie University,Halifax, Nova Scotia, Canada.

Mpodozis C., Marinovic N.,Smoje I. 1993a. Eocene left lateral strike slip faulting and clockwise block rotations in the Cordillera de Domeyko, West of the Salar de Atacama, Northern Chile. 2nd ISAG,Oxford (UK) 21-23/9/1993

Mpodozis C., Marinovic N., Smoje I., Cuitino. 1993b. Estudio Geologico estructural de la Cordillera Domeyko entre Sierra Limon Verde y Sierra Mariposas: Region de Antofagasta. Report.

Pardo-Casas F. & Molnar P. 1987. Relative plate motion of the Nazca (Farallon) and South American plates since Late Cretaceous time. Tectonics v6 : 233-248.

Prinz P., Wilke H.-G., Hillebrandt A. V. 1994. Sediment accumulation and subsidence history in the Mesozoic marginal basin of Northern Chile. Tectonics of the southern Central Andes. Eds, Reutter K.-J., Scheuber E., Wigger P. J.

Reutter K.-J., Scheuber E., Chong G. in press. The Precordilleran Fault System of Chuquicamata, Northern Chile: evidence for reversals along arc-parallel strike slip faults. Tectonophysics.
Sanderson D. J. & Marchini R. D. 1981. Transpression. Journal of Structural Geology, v 6 (5)449-458.
Scheuber E., Bogdanic T., Jensen A., Reutter K.-J. 1994. Tectonic development of the North Chilean Andes in relation to plate convergence and magmatism since the Jurassic. Tectonics of the Southern Central Andes, Eds; Reutter K.-J., Scheuber E., Wigger P. J.
Tomlinson A. J., Mpodozis C., Cornejo P. C., Ramirez C. F. 1993. Structural Geology of the Sierra Castillo - Agua Amarga fault system, Precordillera of Chile, El Salvador - Potrerillos. 2nd ISAG, Oxford (UK), 21-23/9/1993.

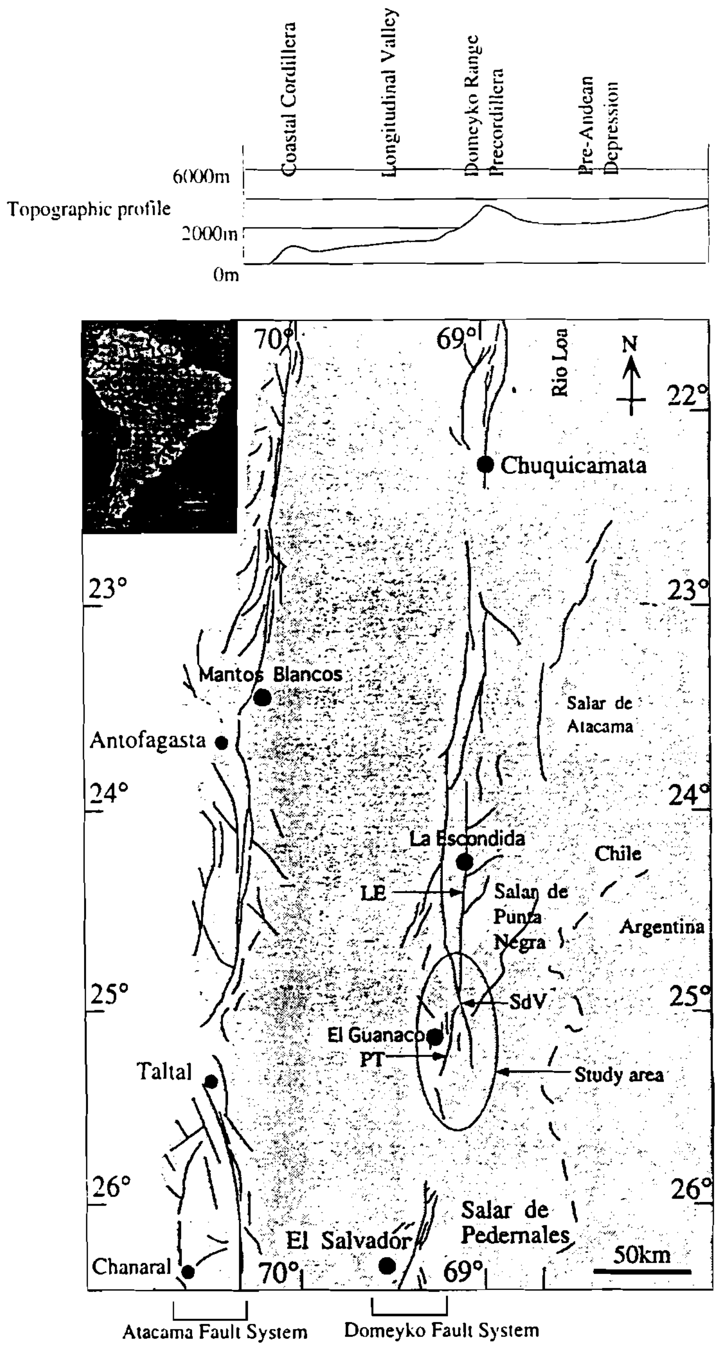

Figure 1, (modified from Prinz et al 1994), showing location, fault system and topographic profile. PT : Profeta Thrust. LE : La Escondida Fault
SdV : Sierra de Varas Fault