FLOW DIRECTION INFERENCES FROM AN AMS STUDY IN FLUVIAL SEDIMENTS OF ALLUVIAL FACIES

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ABSTRACT

Flow directions from anisotropy of magnetic susceptibility (AMS) results from 19 sites (242 samples), were determined. Sites are from several stratigraphic levels of a Triassic-Jurassic, 369 m thick, fluvial sequence, known as La Mora Formation, from southern Mexico. The facies are mostly alluvial, mainly Fl and Fr (Miall facies classification), the dominant lithology of samples is very fine silty sandstone. AMS ellipsoids are mostly prolate (T*mean* = -0.202), anisotropy degree (Pj) range from 1.015 to 1.09 with an average of 1.036, and susceptibility (Km) from 1 to 3 x10-4 SI with an average of 1.9 x10-4 SI. Flow directions inferred from *K1* axis were towards NW, SE and NW alternatively from bottom to top, which allowed to identify three different stratigraphic sections in the sequence. The flow directions switching is compatible to alluvial plain overbank floods toward either side of mainstream. Then, the paleo-orientation of the mainstream should have been NE-SW, and the direction of the general paleo-slope, considering the distribution of the tilt-corrected *K3* orientations, might have been towards the SW (240°).

Keywords: AMS (anisotropy of magnetic susceptibility), flow directions, fluvial sediments, Triassic-Jurassic, Southern Mexico

RESUMEN

Inferimos las direcciones de flujo a partir de resultados de la AMS, obtenidos de 19 sitios (242 muestras), de diferentes niveles estratigráficos, de una secuencia fluvial Triásico-Jurásica, de 369 m de espesor, designada como Formación La Mora, del sur de México. Las facies son dominantemente aluviales, principalmente Fl y Fr (clasificación de facies de Miall), la litología dominante es arenisca limosa de grano fino. Los elipsoides de AMS son prolados en su mayoría (T*media* = -0.202), el grado de anisotropía (Pj) oscila entre 1.015 y 1.09, con un promedio de 1.036 y la susceptibilidad (Km) de 1 a 3 x 10-4 SI con un promedio de 1.9 x 10-4 SI. Las direcciones de flujo inferidas del eje *K1* fueron hacia el NW, SE y NW alternativamente, lo que permitió identificar 3 secciones estratigráficas diferentes en la secuencia. Esta conmutación de las direcciones del flujo es compatible con las inundaciones aluviales hacia ambos lados de la corriente principal. Entonces, la paleo-orientación de la corriente principal debería haber sido NE-SW, y la dirección de la paleo-pendiente general, considerando la distribución de las orientaciones *K3* corregidas de inclinación, podría haber sido hacia el SW (240°).

Palabras clave: AMS (anisotropía magnética de susceptibilidad), direcciones de flujo, sedimentos fluviales, Triásico-Jurásico, Sur de México.

1. Introduction

The studied fluvial sequence is located in the Mixteca Terrane whose Early Mesozoic history, related to the Pangea break-up, is debated (*e.g.* Martini and Ortega-Gutiérrez, 2016; Pindell, J., and Kennan, L., 2009; Dickinson and Lawton, 2001). The sedimentary record of this time is made up of diverse fluvial sequences with a wide type of facies, that outcrop in different places around the towns of Huajuapan de Leon, Oax., to the South, and S. Tomas Otlatltepec, Pue., to the North

(Fig. 1). Provenance studies from these sequences, based on their heavy mineral content: zircons (*e.g.* Silva-R., *et al*., 2015) and zircons and garnets (Martini, M. *et al*., 2016), indicate sources from a lifting basement and give the maximum deposit ages of Late Triassic to Early and Middle Jurassic. Flow current directions from the northern sequences, inferred from flow indicators and AMS studies (Martini, *et al*., 2016 and Caballero-M., 1994, respectively) are towards NW and NE. Flow directions inferences from the coarser-grained sequences of southern outcrops, based on combined AMS results-cross-bedding measurements, suggest inconclusive SSW directions (Caballero-M, 1994).

The present study corresponds to the finest-grained southern fluvial outcrops, defined as La Mora Formation of a Late Triassic-Early Jurassic age (Fig. 1.; Silva-R, *et al*., 2015)

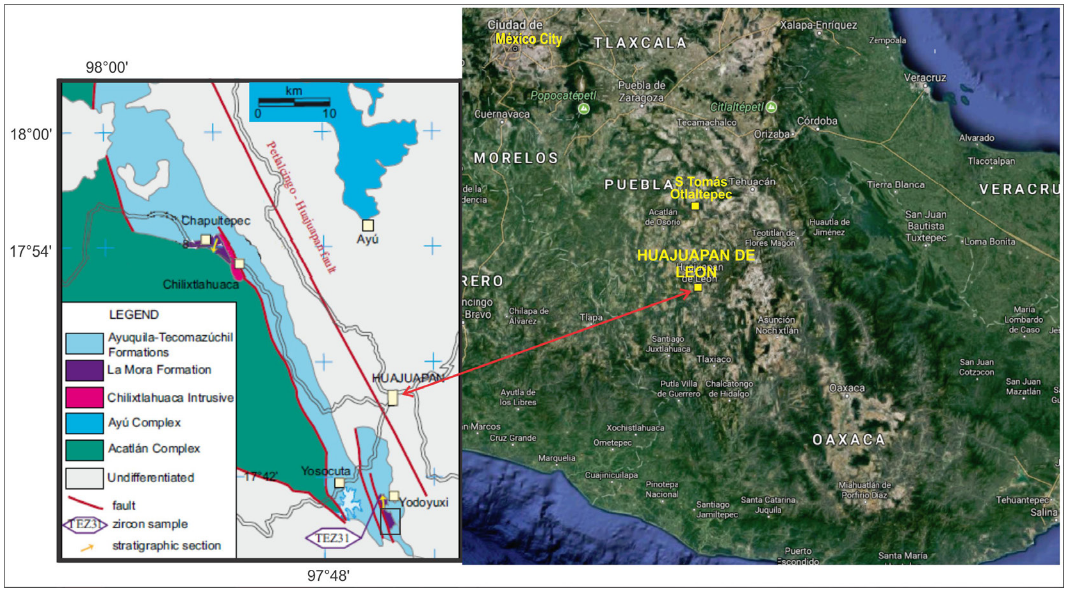

Figure 1. Location of the studied sequence. Right side villages referred in text. Left side geologic map and box where the studied sequence outcrops.

2. Methodology

Employing a portable drill, we sampled the 369 m thick sequence of the stratotype of La Mora Formation in the vicinity of Yodoyuxi, at 19 different stratigraphic levels, each with 8 to 16 specimens (Table 1), obtaining a total of 242 specimens. Levels were selected by trying to cover all types of lithology and facies along the entire sequence where it was feasible to drill. Samples were measured with a KLY2 Agico instrument. Results were processed with the Anisoft.4 software. At each site, results were tilt-corrected, the principal AMS mean directions were calculated with their corresponding parameters, and then a flow direction was inferred. The means of all sites were later processed with the Anisoft.4 software and subjected to a density distribution statistic in order to analyze a possible general flow direction from the entire sequence, tentatively corresponding to the whole fluvial system.

3. Results

The AMS results are shown in Table 1 and Figure 2, arranged in 3 groups according to their stratigraphic position. Stratigraphic levels in the sequence and vertical variations of parameters are in Figure 3. AMS ellipsoids are mostly prolate all along the sequence, but below 115 m there are more oblate shapes ellipsoids (T*mean* = 0.294) with higher anisotropy degrees (Pj*mean* = 1.044)

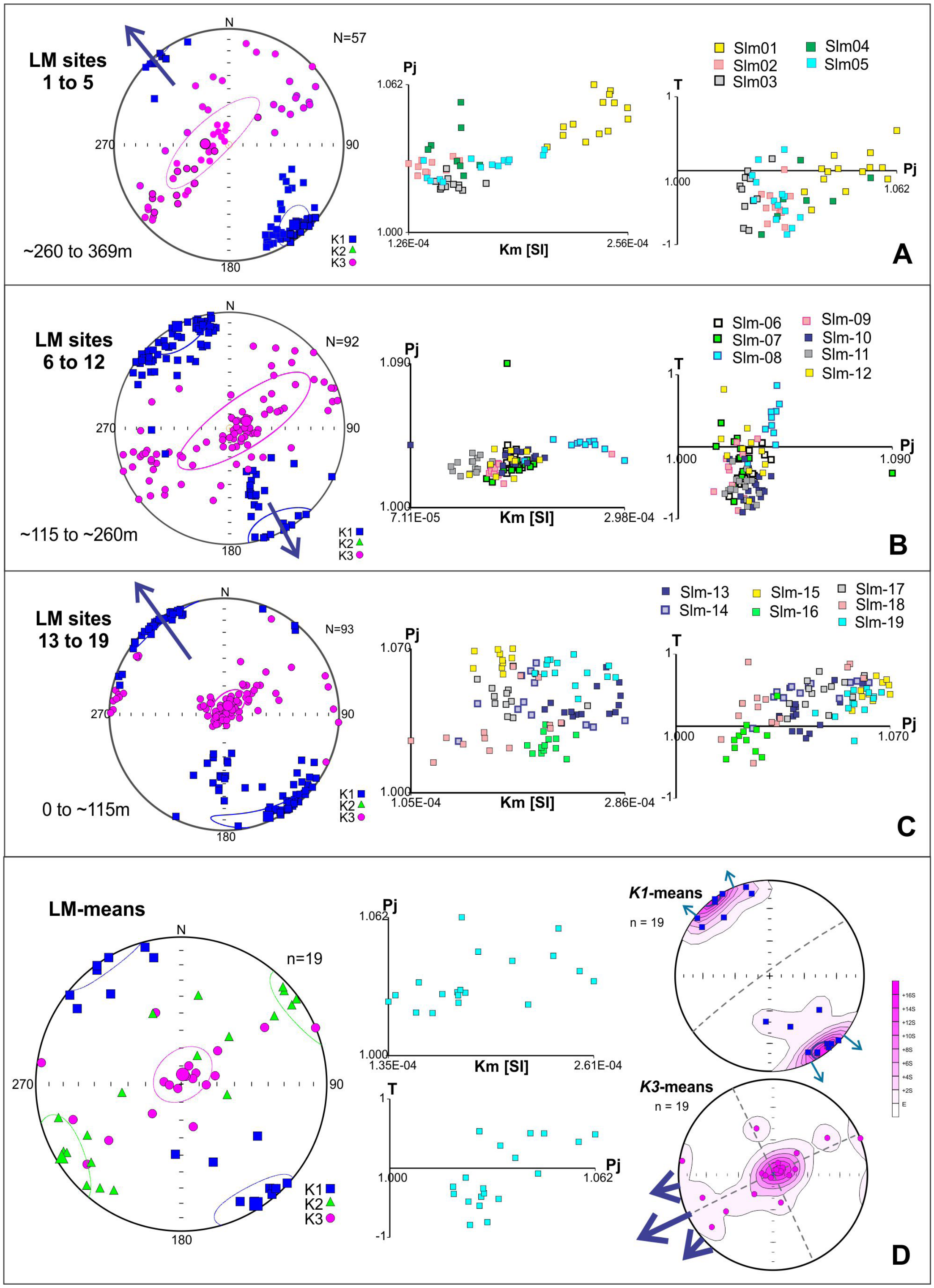

Figure 2. AMS results at different stratigraphic sectors: A, B and C, and of the AMS mean of sites in D. All AMS directions are tilt-corrected and plotted in lower hemisphere of equal-area polar projections. Graphs of Km, Pj and T parameters of each sector correspond to all specimens, and in D correspond to the mean of sites. The arrows in A, B and C indicate the flow direction inferences of the overall samples of each sector. In D, the density distribution of *K1* and *K3* axis is shown with the flow directions inferred from *K1* axis, for alluvial overbank floods, and flow direction of mainstream inferred considering *K3* axis distribution

Table 1. AMS results of La Mora Fm.

Sites	height	Facies	n	Km 10 E-4	Pj	T	*K1* dec	*K1* inc	*K1* Conf Ang	*K3* dec	*K3* inc	*K3* Conf Ang
LM-01, to 05	260-369	1 Sp, 3 Fl, 1 Fr	57	1.75	1.027	-0.681	140	11	11/16	273	73	13/46
LM-06, to 12	115-260	1 Sm 2 Fl 2 Fr 2 Sl	92	1.8	1.019	-0.742	333	1	37/21	67	77	17/58
LM-13 to 19	0 - 115	1 Sm 1Sl 1 Sr 4 Fl	93	2.12	1.031	0.261	156	5	7/31	23	83	9/14
Aver				**1.893**	1.034	-0.098						
Mean					**1.024**	**-0.202**	**148**	**4**	13/18	**9**	**85**	13/18

Stratigraphic height is in meters from base of the stratotype in the vicinity of Yodoyuxi (Silva-R., 2015). Facies keys are from Miall (1996), each key is for one site (Fig. 3). Km values are in SI units, n is number of samples; Conf Ang is confidence angles

and higher susceptibility (Km*mean* = 2.12 x10-4); whereas above 115 m ellipsoids are mostly prolate (T*mean* = -0.294) with slightly lower anisotropy degrees (Pj*mean* = 1.031) and lower susceptibility (Km*mean* = 1.77 x10-4).

All results within each site show very well organized magnetic fabrics, with several similarities among sites, although there are some relevant differences from one site to another. AMS tilt-corrected directions show nearly horizontal *K1* axis that is always the best concentrated axis, and *K3* axis frequently with sub-vertical positions or showing different inclination values, apparently switching positions with *K2* axis along NE-SW sub-vertical planes. AMS results from the sites Slm-04, Slm-10 and Slm-13, show *K1* axis inclination higher than 33° suggesting that these sites are in faulted blocks, and then these results should be taken cautiously.

4. Flow inferences discussion

Flow direction inferences at each site were inferred from *K1* axis orientations and sometimes considering *K3* axis orientation as an additional indicator of imbrication of ellipsoids. The inferred flow directions allowed to identify 3 different stratigraphic sections in the sequence. The flow direction in the upper part is inferred towards NW (325°); in the middle part to towards SE (160°); and in the lower towards NW (325°) (Fig. 2). This switching of flow directions is compatible to alluvial plain overbank floods toward either side of mainstream. If so, the paleo-orientation of the mainstream should have been nearly perpendicular to these orientations: NE-SW (Fig. 2D), and the direction of the general paleo-slope, considering the distribution of the tilt-corrected *K3* orientations, might have been towards the SW (240°).

5. Conclusions

Additional paleocurrent indicators, such as cross-bedding dip, which is frequently observed in the sequence, should be integrated in order to assess a final conclusion about flow direction of mainstream and position of main source of sediments. Magnetic mineralogy studies, presently in course, may give also additional information about kind of source rock of sediments.

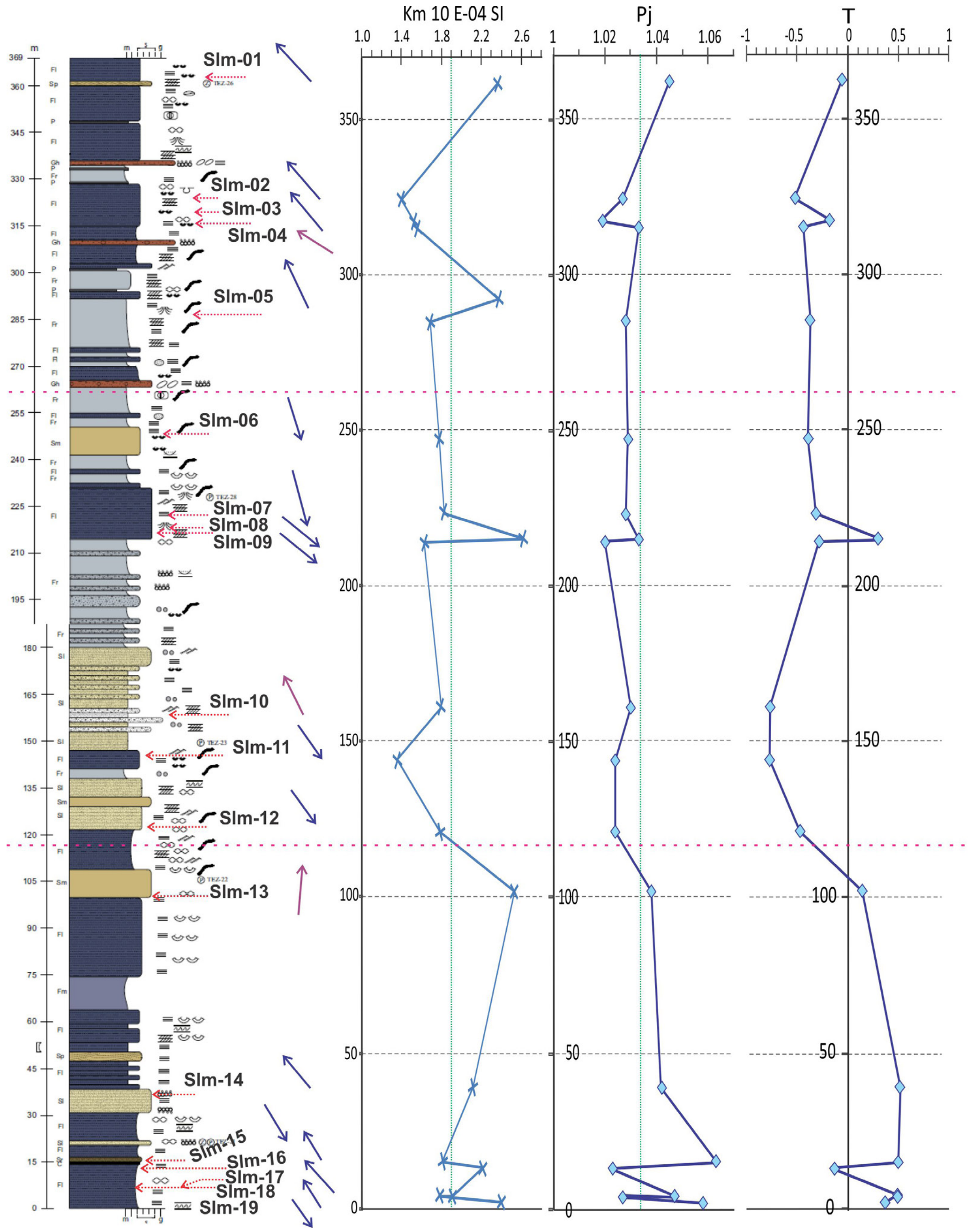

Figure 3. Position of sampled sites (red horizontal dotted arrows) in the stratigraphic sequence with flow direction inference at each level (blue arrows). Sectors described in text and Figure 2 are delimited by horizontal pink dotted lines. The graphs on the right side show the vertical variation of the mean of the parameters Km, Pj and T.

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