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Tephra Samples from the 2005-2006 Archaeological Excavations at La Alberca and Associated Archaeological sites, Michoacán, México

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Abstract: Tephrochronology is an excellent tool which can help correlate and date archaeology and palaeoenvironmental sediment sequences. It also allows connections to be made between archaeology and surrounding landscape, which is a great help for environmental archaeological studies. Michoacán, central México, is dominated by monogenetic volcanic activity. Tephra produced from these eruptions can have a significant impact on human societies close to the volcanoes and more distally transported layers have been used to correlate and date lacustrine sediment sequences in Michoacán. This study has demonstrated that the recent Paricutín (1943-1952) tephra is found throughout this area and provides a modern analogue on how reworking of old tephra layers occurred. It is also apparent that whilst tephrochronology has the potential to provide useful correlations, the relative lack of comparative data is a problem which can only be dealt by carrying out more tephrochronological studies in the region. Trace element analyses are also required to discriminate between tephra layers with very similar major and minor element compositions.
Keywords: tephrochronology, environmental archeology, Paricutín.

Resumen: la tefrocronología es una herramienta excelente que puede relacionar y datar arqueología y secuencias sedimentarias palaeoambientales. También permite crear conexiones entre la arqueología y el paisaje que rodea el yacimiento, lo que es de gran ayuda para los estudios arqueológicos ambientales. En Michoacán, situado en el centro de México, se caracteriza por la actividad volcánica, por lo que a su geología se refiere. El tefro producido por las erupciones puede tener un gran impacto en las sociedades humanas que sen encuentran cerca de los volcanes; los sedimientos volcánicos han servido para correlacionar y datar secuencias de sedimentos lacustres en Michoacán. Este estudio persigue demostrar que el reciente tefro Paricutín (1943-1952) que se encuentra en esta área geográfica provee una analogía moderna de cómo se redistribuyeron las antiguas capas de tefro. Es obvio que mientras la tefrocronología tiene el potencial de proveer correlaciones útiles, la falta comparativa de datos es un problema que solo se puede resolver conforme se hacen más estudios tefroconológicos en esta zona además de otros tipos de análisis.
Palabras clave: tefrocronología, arqueología ambiental, tefra de Paricutín.

Michoacán-Guanajuato Volcanic Field

The Michoacán-Guanajuato volcanic field (MGVF) is unusual in that it is not dominated by a large central volcano, but by monogenetic activity which has produced a large number of cinder cones and shield volcanoes. Only two stratovolcanoes are found in the area, the extinct Cerro Tancítaro and Volcán Grande. By contrast, Hasenaka and Carmichael (1985a, b) catalogued some 900 cinder or lava cones in the 40,000 km^2 of the MGVF. Hasenaka and Carmichael (1985a; 1985b) estimate some 70-80 were erupted during the last 40,000 years and the remainder during since 400,000 years BP. The youngest cones are found within the southern part of the MGVF and approximately 16 cones are estimated to have erupted during the Holocene, giving an eruption rate of around two per 1000 years (Hasenaka and Carmichael, 1985a, b; Ban *et al*., 1992; Hooper, 1995). The two most recent monogenetic cones in the MGVF are Jorullo (AD 1759-1774) and Parícutin (AD 1943-1952).

Parícutin is an iconic scoria cone and is typical of the many similar cones found within the MGVF. As the only eruption to occur during the 20th century, it has been well-studied both proximally and more distally. Lava from the 1943-1952 eruption of Parícutin covered nearly 25 km^2 and built up a scoria cone 424 metre high. Total tephra output was approximately 1.3 km^3 and 300km^2 was covered to a thickness of greater than 15 cm (Luhr and Simkin, 1993). Tephra from the eruption travelled as far as México City, some 320 km away. Ort *et al*. (2008) discuss the impact of the eruption on local communities and an excellent contemporary description of the eruption can be found in Foshag and González (1956). The eruption also had an impact on the dendrochronological record of pines found close to Parícutin (Sheppard *et al*., 2008). Tephra from 1759-1774 eruption of Jorullo fell over 200 km away in Queretero and blocked out the sun in Pátzcauro (60 km) and Morelia (100 km) (Gadow, 1930; Moreno, 1986). These accounts demonstrate that these relatively small volcanic eruptions can have a large impact on proximal communities. Ort *et al*. (2008) discuss the negative and positive impacts of these types of eruption on nearby societies. Whether tephra from this eruption is beneficial or not depends not only tephra thickness, but also on whether the area is arid or more humid.

The accounts mentioned above emphasise that monogenetic activity in the MGVF can produce tephra deposits, which are widely distributed. Identification, correlation and dating of tephra layers in sediment sequences can be an invaluable tool in archaeological and palaeoenvironmental studies (Lowe, 2011). Newton *et al.* (2005) identified the Parícutin and Jorullo tephras in lake cores from lakes Zirahuén and Pátzcuaro and these were used to correlate cores and provide valuable chronological control to palaeoenvironmental records (Davies *et al.*, 2004; Metcalfe *et al.*, 2007; Ortega et al., 2010). The Parícutin tephra has also been found in maar sediments in the Valle de Santiago, some 150 km to the north-west of the volcano (Kienel, 2009). The impact of tephra layers on lake ecosystems in Michoacán were investigated by Telford *et al.* (2005).

Archaeological Tephra Samples

Tephra samples were provided from the archaeological and related fieldwork in the area close to Parícutin. La Alberca is a volcanic crater found approximately 7.5 km east of Parícutin. El Marciano is found approximately 1 km south-east of La Alberva. Tephra layers were exposed in sections in fields. La Loma (Jose's Field) is found just to the west of Nuevo San Juan Parangaricutrio, approximately 14km south-east of Parícutin. Further details about the tephra deposits themselves can be found in Trosper (2006) and this paper concentrates on geochemical analyses.

Methodology

A total of 14 tephra samples were analysed using an electron microprobe to establish their major and minor element composition (Appendix 1). Tephra shards were incorporated into resin on a glass slide and then ground and polished to a thickness of 75 µm. These slides were then analysed by the Wavelength Dispersive technique on a Cameca SX100 electron microprobe (School of GeoSciences, University of Edinburgh) using an accelerating voltage of 20 kV, a beam current of 4 nA and beam diameter of 10 µm. Count times were 10 seconds and instrumental stability was checked using glass standards. PAP correction was used to account for counter deadtime, atomic number effects, fluorescence and absorption. Total iron is expressed as FeO.

Results

The results are presented in Appendix 1. The majority of the analyses were basaltic andesite to andesitic in composition (Figure 1). Virtually all analyses are between 52-59% SiO_2, with only 2 being more than 60%. This is typical for the tephra erupted from monogenetic cinder cones in the MGVF and is similar to the analyses found in Newton *et al.* (2005).

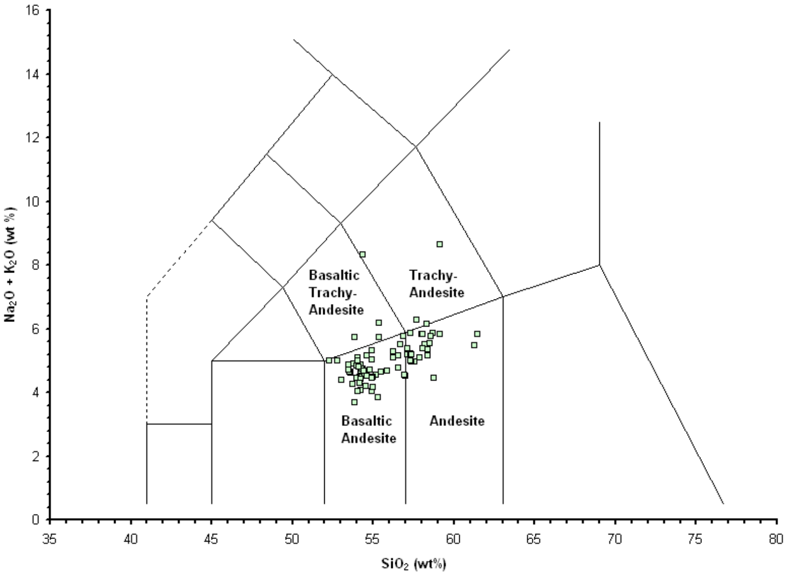

Figure 1: Total Alkali Silica (TAS) to show compositional range of tephra samples.

Alberca Caldera Trench 2

Four tephra layers were analysed from Alberca Caldera Trench 2. The uppermost layer, **T2 S7 (61-78 cm)**, has been interpreted as Parícutin deposited 1943-1952, although most tephra was produced during the first 2 years (Fries, 1953). Parícutin is only 7.5 km distant from the Alberca Caldera which is close to the 25 cm isopach for the initial deposition (Ort *et al.*, 2008). T2 S7 is geochemically similar to published analyses of the Parícutin tephra (Figure 2) and can so be interpreted as having being deposited in the mid to late 1940s. It is highly likely that much of the deposits of Parícutin have been reworked and are no longer *in situ*.

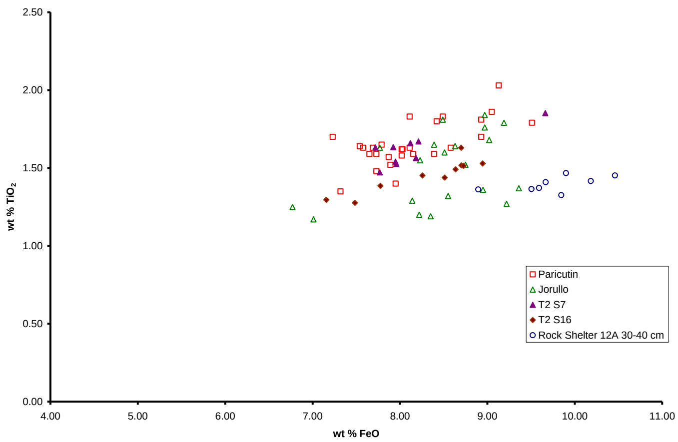

Figure 2: Parícutin and Jorullo are similar in composition, but there are differences, with Jorullo having generally lower TiO_2 than Parícutin (Newton *et al.* 2005). T2 S7 matches Parícutin well, whilst T2 S16 is more like Jorullo, but has a more limited compositional range.

Tephra sample **S16 (181-184 cm)** was radiocarbon dated to 580±40 BP (calibrated to 1297-1422 AD). This tephra is geochemically more similar to the Jorullo tephra (Figure 2), although with an older date and more limited geochemical range it is seems unlikely it can be correlated to the 1759-1774 eruption. Presumably this was erupted from an unknown eruption from a nearby cinder cone.

Sample **T2 S27 (454-456 cm)** is radiocarbon dated to 2300±40 BP (412-207 BC). This again does not match with any known activity in this area, but the geochemistry of this layer is similar to Parícutin and sample T2 S7 (Appendix 1).

The deepest tephra layer **T2 540-550** cm has a more basaltic component than any of the other layers in Trench 2 (Appendix 1), with correspondingly higher abundances of MgO, FeO and CaO. It also contains less P_2O_5 than any of the other layers.

Caldera Trench 1

Unfortunately it was not possible to obtain enough good quality analyses from **#406 (A.D. 270-280 1870±40 BP)** tephra layer.

Tephra layer **#520 (500-550 cm)** is the lowest tephra layer in Caldera Trench 1. It appears to have two distinct components, as two analyses produced SiO_2 abundances of 61% (with correspondingly low MgO, FeO and higher K_2O), compared to the more representative 54-58% SiO_2 found in other monogenetic tephras in this area (Appendix 1). A correlation with T2 540-550 cm was suggested by Lisa Ely (pers. comm.) and apart from the two high SiO_2, Appendix 1 and Figure 3 suggest such a correlation is possible. The geochemistry is similar and occupies a comparable compositional range.

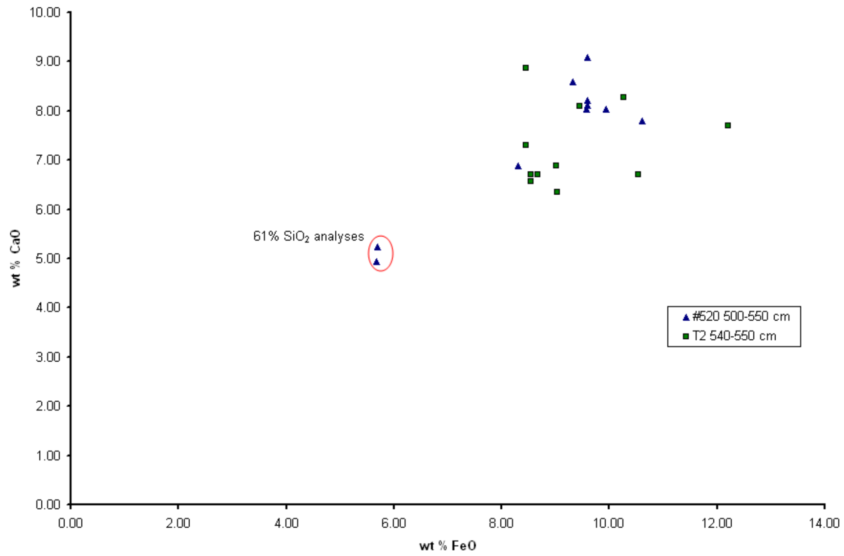

Figure 3: Illustrates the similarity between #520 from Caldera Trench 1 and T2 540-550 cm from Trench 2.

Rock Shelter 12A

Tephra sample **30-40 cm** is distinctive due to its comparatively low SiO_2 (less than 55%) and is fairly homogeneous. It was suggested that this is part of the Parícutin tephra, but the geochemistry shown in Appendix 1 and Figure 2 demonstrate that this is unlikely. It is more similar to Jorullo, although the 30-40 cm tephra has lower SiO_2, higher CaO and FeO and lower K_2O than Jorullo.

Appendix 1 shows that tephra **3.4-3.5 m** is similar to 30-40cm, the same homogeneous, low SiO_2 composition with some minor variations, but overall it might seem possible that 30-40 cm could possibly be derived from the deposit as 3.4-3.5 m.

La Alberca (2006)

Sample **217 ALB (185-200 cm)** from Pit 3 is a dark to black tephra with a base approximately 40 cm below a radiocarbon date of 560-680 BP (AD 1270-1390). The profile in between this tephra and the radiocarbon dated charcoal layer consists of four tephra units in silty sediment, which is interpreted as reworking of older tephra deposits (Trosper, 2006). This means that the tephra must be somewhat older than 560-680 BP, although the precise age is unknown. Trosper (2006) suggest a correlation with the similarly dated S16 (181-184 cm) from Alberca Trench 2. Stratigraphically this correlation makes sense, but geochemically there are some differences between the two layers. Appendix 1 and Figure 4 show that although the two layers are geochemically similar, 217 ALB (185-200) has slightly higher SiO_2, P_2O_5, K_2O and TiO_2 and lower CaO and FeO than S16 (181-184 cm). Figure 4 is typical and shows the overlap, but generally higher P_2O_5 and K_2O abundances of 217 ALB. The 217 ALB layer is also similar to the much younger S7 layer from the Alberca Trench 2, but the much younger date of this layer would suggest a correlation is simply not possible. Given the close proximity, the stratigraphic and chronological similarities, it would seem that despite the somewhat ambiguous geochemical similarities, 217 ALB and S16 (181-184 cm) can be correlated.

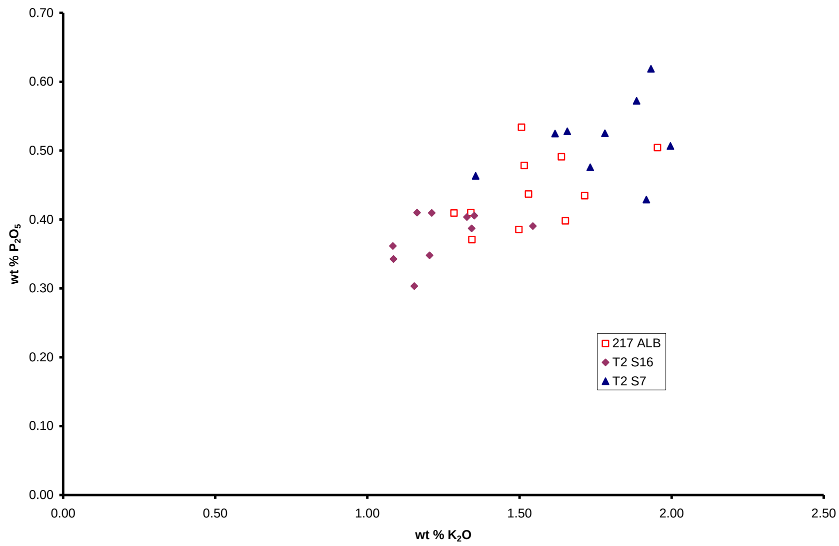

Figure 4: There is overlap between 217 ALB and T2 S16 and they also appear to be on a similar trend. There is also overlap between 217 ALB and T2 S7, although stratigraphic and chronological evidence means a correlation between these is unlikely.

Marciano

Unfortunately, **Marciano Yacata 3** did not produce enough good quality analyses.

Although only 4 analyses were obtained, **Marciano Roadcut #1 112-147** had consistently high P_2O_5 similar to T2 S27, although a correlation is not possible, however, due to difference in other oxides, such as lower SiO_2 in #1 112-147 (Appendix 1). Unfortunately both layers produces only small numbers of analyses.

Marciano Roadcut #2 184+ is similar to Caldera Trench 1 #520 (500-550 cm) and Caldera Trench 2 T2 540-550 (Figure 5, Appendix 1). #2 184+ seems to have higher P_2O_5, than either of the other two tephras, and higher FeO, although this might be because there are more lower SiO_2 analyses of the sample tephra than in the other two (possibly different parts of the same layer). A tentative correlation between #2 184+ and #520 (500-550 cm) and T2 540-550 is proposed.

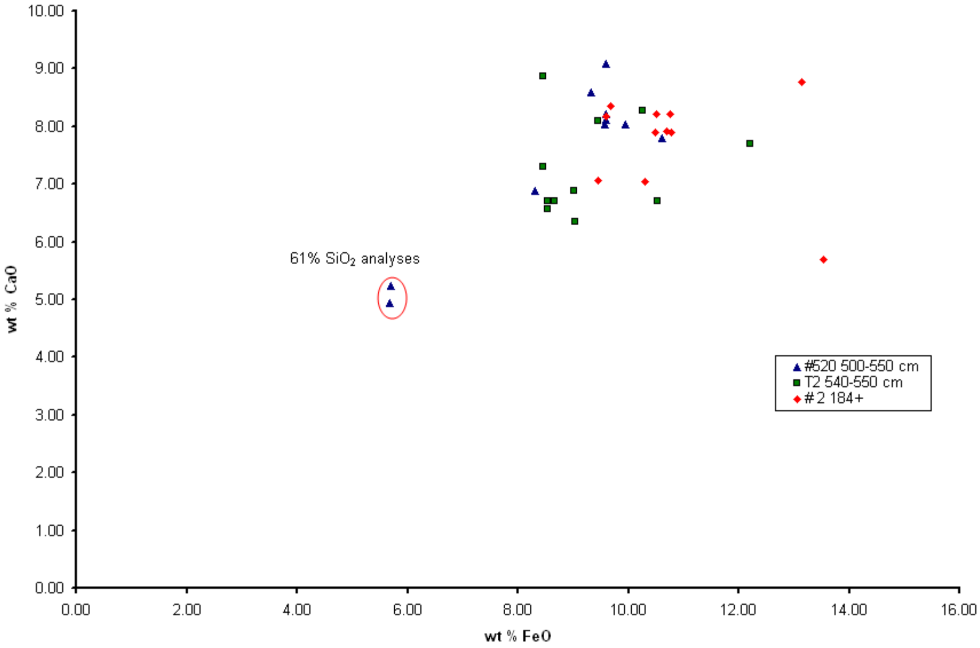

Figure 5: shows the similarities between the three tephra deposits.

La Loma

The **3-LOM-T-Pit 2 tephra** from 20 cm depth at La Loma is radiocarbon dated to between AD 1440-1640. All of the analyses are shown in Appendix 1 and these suggest the tephra is one of the more basic layers analysed in this project, with SiO_2 abundances of between 53-56%. Unfortunately some of the analyses have elevated Al_2O_3 analyses which suggest partial analysis of feldspar phenocrysts, typical of Mexican tephras (Ortega and Newton, 1998 and Newton *et al.*, 2005). These analyses are kept to illustrate the type of tephra, which is a relatively basic basaltic andesite. Despite this it is clear that the nearest tephra in composition to 3-LOM-T-Pit 2 tephra is the tephra analysed 30-40 cm in Rock Shelter 12A. This is a tentative correlation, as the upper tephra in Rock Shelter 12A was thought to be Paricutín, but is not due to a significantly lower SiO_2 content. Further analyses of 3-LOM-T-Pit 2 without the feldspar problem might clarify this.

Tumbiscatillo

Tumbiscatillo road cut tephra sample **407 (T2)** is most geochemically similar to the 217 ALB tephra from La Alberca (Appendix 1, Figure 6). There is also considerable overlap with S16 (181-184 cm) from Alberca Trench 2. Both of these tephras were correlated above. There is little stratigraphic or dating evidence from the Tumbiscatillo profile, so it is difficult to be definite about any correlation without other data to support it. Despite this, it can be said that the Tumbiscatillo tephra is geochemically similar to the 217 ALB and Alberca Trench 2 tephras.

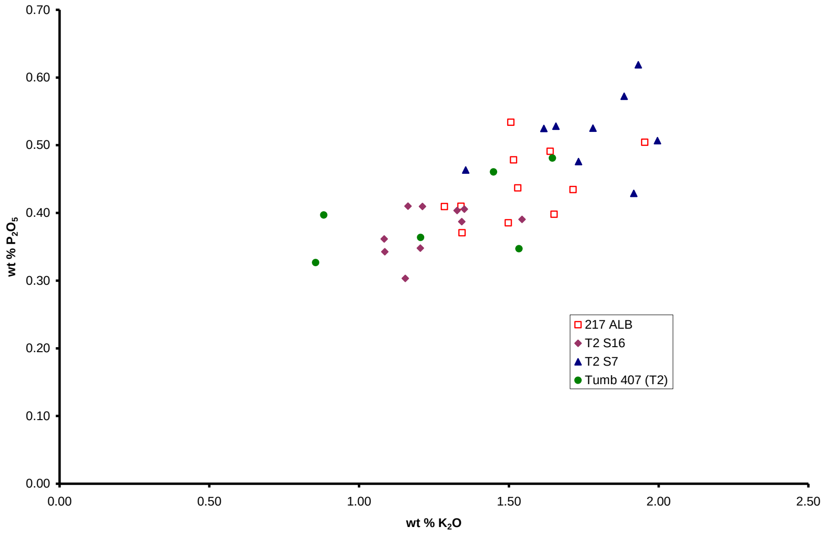

Figure 4: Demonstrates the similarity between the Tumbiscatillo tephra and the two La Alberca layers.

Discussion and Conclusions

Despite the problems of limited comparative data, including the lack of knowledge of the recent volcanic history of this area and in particular the age of just pre-Hispanic monogenetic cinder cones, it has been possible to make some correlations based on a combination of stratigraphy, chronology and geochemistry. It is not surprising that the nearby Parícutin tephra is present (e.g. T2 S7 (61-78 cm), although the 30-40cm sample from the Rock Shelter 12A, which was identified as being Parícutin is probably not. The 217 ALB and Alberca Trench 2 tephra from La Alberca also seems to appear in the Tumbiscatillo section, 407 (T2); although this correlation is tentative. There is another possible correlation between the Rock Shelter 12A 30-40 cm tephra and the La Loma 3-LOM-T-Pit 2 layer.

The usual problems of poor quality Mexican volcanic glass shards, containing mineral microlites and phenocrysts which contaminate glass analyses and a lack of glass at all in some samples (Ortega and Newton, 1998 and Newton *et al.*, 2005), meant that it was not possible to always achieve a satisfactory number of analyses or analyse successfully every sample. Further analysis may make it possible to achieve more analyses, but there is a limit to the amount of time that can spent on the instrument trying to obtain a few more analyses.

Perhaps the biggest the problem is the lack of comparative data. Although lake sediments have produced an important record of Late Quaternary tephra layers (e.g. Newton *et al.*, 2005), the lakes are between 40-80 km from the archaeological sites and only a little information is known about the age of nearby cinder cones (Hasenaka and Carmichael, 1985; Newton *et al.*, 2005) which could have supplied the tephras seen in the profiles (both primary and reworked). It is clear from this work that several eruptions have produced tephra which are not found in the lake cores and have been erupted from nearby cinder cones, whose ages are not known. Further work in this area involving mapping of tephra units to individual cones would help establish the tephrostratigraphy for this region. Tephra layers such as Las Alberca S16 (181-184cm), 217 ALB (185-200 cm) and possibly the Tumbiscatillo tephra layer could be useful regional markers if there distribution was mapped and geochemistry established more confidently. This paper used major and minor element electron microprobe analyses and it is apparent that the use of trace element data may well be necessary to discriminate between individual monogenetic eruptions. Laser ICP-MS provides a technique which could be employed to help find geochemically differences between tephra layers with very similar major and minor element characteristics (Pearce et al., 2007).

It is evident that the reworking of tephra is a major problem when it comes to using tephrochronology to help date archaeological sites. Such a dynamic landscape provides challenges, but this work has shown that tephrochronology can help to date profiles and provides the potential of correlation to palaeoenvironmental records (Metcalfe *et al.*, 2007; Davies *et al.*, 2004). Dugmore and Newton (2012) emphasised that reworking of tephra layers provides information on landscape stability and great opportunities to understand the processes by which tephra layers become part of the geological record.

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Appendix 1: Geochemical data

Alberca Trench 2

T2 S7 (61-78 cm)

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
59.12	1.54	14.52	7.95	0.16	3.40	5.72	3.89	1.93	0.62	98.85
58.73	1.85	13.65	9.66	0.23	3.47	6.17	3.11	1.36	0.46	98.68
58.72	1.66	14.06	8.12	0.16	3.47	5.67	3.98	1.88	0.57	98.31
58.56	1.63	14.48	7.72	0.19	3.55	5.73	3.98	1.78	0.53	98.15
58.51	1.67	14.05	8.21	0.16	3.39	5.70	3.62	1.92	0.43	97.65
58.20	1.47	15.42	7.77	0.22	3.53	5.89	3.84	1.66	0.53	98.52
58.03	1.56	14.47	8.18	0.20	3.46	5.83	4.08	1.73	0.48	98.03
57.33	1.63	14.77	7.92	0.18	3.11	5.99	4.23	1.62	0.52	97.31
57.10	1.53	14.99	7.96	0.13	3.46	5.57	3.20	2.00	0.51	96.44

T2 S16 (181-184 cm)

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
56.27	1.44	15.21	8.51	0.18	3.59	6.86	3.87	1.21	0.41	97.63
56.97	1.45	14.91	8.26	0.18	3.45	6.80	3.32	1.20	0.35	96.97
55.52	1.49	14.54	8.64	0.21	3.77	6.77	3.55	1.09	0.34	95.99
56.54	1.63	14.06	8.70	0.14	3.76	6.18	3.43	1.33	0.40	96.24
56.22	1.30	16.32	7.16	0.21	3.38	7.65	4.19	1.08	0.36	97.87
57.59	1.28	16.64	7.48	0.14	3.23	7.21	3.82	1.15	0.30	98.84
56.68	1.39	15.74	7.78	0.20	3.27	6.96	4.33	1.16	0.41	97.92
57.31	1.52	14.49	8.70	0.13	3.79	6.27	3.88	1.34	0.39	97.82
57.14	1.51	14.55	8.73	0.15	4.04	6.37	3.80	1.54	0.39	98.23
57.11	1.53	14.11	8.95	0.12	3.80	6.43	4.02	1.35	0.41	97.82

T2 S27 (454-456 cm)

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
58.38	1.75	13.64	8.68	0.09	3.15	5.95	3.78	1.57	0.35	97.33
58.29	1.81	14.36	8.73	0.21	2.83	5.93	4.86	1.29	0.37	98.67
58.09	1.72	13.80	8.91	0.22	3.33	5.57	3.98	1.84	0.37	97.82
58.06	1.76	13.93	8.97	0.16	3.38	6.22	3.89	1.50	0.36	98.22
57.66	1.69	15.05	8.24	0.14	2.77	6.25	4.44	1.82	0.26	98.32

T2 540-550 cm

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
57.90	1.44	15.23	8.45	0.11	2.97	7.30	4.10	0.99	0.31	98.80
57.36	1.61	14.69	8.66	0.22	3.06	6.71	3.67	1.52	0.27	97.84
57.34	1.62	14.48	8.54	0.25	3.29	6.57	3.63	1.32	0.27	97.38
57.30	1.63	14.03	8.53	0.15	3.75	6.71	3.46	1.55	0.32	97.51
56.93	1.54	14.18	9.01	0.18	3.65	6.88	3.10	1.44	0.27	97.27
56.54	1.63	13.89	9.03	0.19	3.34	6.34	3.56	1.59	0.36	96.48
55.29	1.52	14.51	10.53	0.20	3.60	6.71	2.48	1.36	0.30	96.49
54.46	1.57	14.54	10.26	0.19	4.79	8.27	3.59	0.92	0.24	98.82
54.04	1.44	14.78	9.45	0.21	4.60	8.09	4.14	0.96	0.28	98.09
53.85	1.61	13.33	12.21	0.23	4.10	7.69	2.48	1.20	0.25	96.96
53.04	1.37	14.35	8.45	0.17	4.72	8.86	3.57	0.82	0.24	95.69

Caldera Trench 1

#520 (500-550 cm)

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
61.48	1.09	15.56	5.68	0.06	1.38	4.94	3.85	1.98	0.31	96.34
61.29	1.01	15.34	5.69	0.11	1.53	5.24	3.32	2.15	0.31	95.99
58.37	1.50	14.79	8.31	0.18	3.34	6.88	3.77	1.37	0.29	98.79
55.16	1.38	15.11	9.60	0.19	4.17	8.11	3.59	0.95	0.27	98.54
54.95	1.39	14.83	9.33	0.20	4.96	8.58	2.54	1.49	0.20	98.49
54.55	1.51	14.34	10.61	0.23	4.54	7.80	3.09	1.09	0.25	98.01
54.49	1.40	14.97	9.59	0.17	4.82	8.21	4.03	0.66	0.31	98.66
54.21	1.48	14.21	9.58	0.10	4.95	8.03	3.75	0.92	0.28	97.50
53.77	1.38	15.78	9.60	0.24	4.70	9.09	4.05	0.83	0.23	99.66
53.61	1.48	14.04	9.94	0.20	4.98	8.04	3.54	1.11	0.21	97.16

Rock Shelter 12A

30-40 cm

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
54.99	1.33	14.86	9.85	0.16	4.73	8.12	3.07	1.10	0.23	98.43
54.77	1.36	14.49	8.90	0.22	4.38	7.85	3.52	1.18	0.23	96.91
54.35	1.41	14.54	9.67	0.17	4.72	8.01	3.78	0.96	0.21	97.81
54.26	1.37	14.23	9.59	0.20	4.87	8.04	3.86	1.00	0.28	97.69
54.23	1.45	14.28	10.46	0.21	5.00	8.04	3.80	0.95	0.25	98.66
54.00	1.47	14.44	9.90	0.25	4.90	8.09	3.87	0.97	0.27	98.15
53.97	1.42	14.36	10.18	0.24	4.96	8.03	3.49	0.95	0.23	97.84
52.78	1.36	15.88	9.50	0.22	4.68	8.65	4.08	0.91	0.27	98.35

3.4-3.5 metres

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
55.86	1.63	13.71	11.44	0.26	4.00	6.85	3.68	1.00	0.32	98.75
54.98	1.35	13.80	9.78	0.21	4.56	8.14	3.40	1.07	0.30	97.57
54.95	1.38	14.76	9.87	0.20	4.60	8.32	4.02	1.00	0.31	99.41
54.27	1.43	13.38	9.80	0.19	4.71	8.30	3.65	1.07	0.28	97.09
54.26	1.40	13.97	9.76	0.22	4.67	8.50	3.40	1.01	0.30	97.49
54.17	1.38	13.38	9.77	0.22	4.60	8.47	3.25	1.03	0.31	96.58
54.03	1.40	13.94	9.97	0.24	4.61	8.06	3.86	1.13	0.37	97.62
53.56	1.35	13.79	9.46	0.12	4.68	8.18	3.67	0.97	0.29	96.07

Marciano Roadcut

#1 112-147 cm

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
55.39	1.50	15.15	8.46	0.22	3.49	8.58	5.08	1.09	0.62	99.58
55.38	1.48	16.36	10.60	0.14	2.82	6.38	4.16	1.56	0.49	99.37
54.90	1.64	14.76	9.10	0.21	3.86	6.93	2.94	2.37	0.56	97.26
54.64	1.66	14.68	9.42	0.15	3.67	7.17	2.92	2.23	0.56	97.09

#2 184 + cm

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
56.85	1.91	15.23	9.45	0.21	2.92	7.06	4.28	1.47	0.43	99.81
54.93	1.55	14.11	10.48	0.20	4.26	7.90	3.35	1.10	0.42	98.31
54.63	1.57	13.85	10.70	0.21	4.63	7.91	3.37	1.14	0.42	98.44
54.43	1.49	14.39	9.68	0.23	4.80	8.35	3.78	0.91	0.36	98.42
54.21	1.56	14.07	10.30	0.22	5.88	7.05	2.54	1.51	0.35	97.69
54.09	1.49	13.95	10.76	0.28	4.83	8.22	3.74	1.07	0.33	98.76
54.04	1.52	13.56	10.50	0.19	4.58	8.21	3.04	1.01	0.30	96.94
53.85	2.18	15.43	13.54	0.19	2.96	5.69	4.70	1.01	0.32	99.87
53.72	1.47	13.95	9.59	0.18	4.38	8.18	3.29	0.98	0.34	96.08
53.50	1.50	13.96	10.78	0.05	4.73	7.89	3.58	1.13	0.26	97.38
52.26	1.52	13.41	13.15	0.16	5.32	8.78	3.80	1.18	0.40	99.97

La Alberca (2006)

217 ALB (185-200 cm)

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
59.47	1.95	14.54	9.20	0.17	2.04	5.56	3.46	1.64	0.49	98.52
59.07	1.57	14.52	8.66	0.06	2.32	5.21	4.04	1.34	0.41	97.20
58.31	1.77	13.13	9.65	0.19	3.15	5.95	3.41	1.51	0.53	97.61
57.98	1.73	14.40	9.28	0.21	2.62	5.28	3.27	1.71	0.43	96.92
57.82	1.77	13.09	8.91	0.18	3.09	5.88	2.76	1.95	0.50	95.94
57.70	1.59	15.19	8.84	0.24	2.87	7.15	3.29	1.29	0.41	98.56
57.45	1.75	14.02	8.59	0.15	3.52	5.79	3.45	1.53	0.44	96.69
57.45	1.53	14.62	8.81	0.22	3.45	6.13	3.46	1.50	0.39	97.56
57.43	1.63	14.33	9.09	0.25	3.82	6.17	3.31	1.52	0.48	98.04
57.43	1.57	14.37	8.74	0.20	3.56	6.20	3.38	1.34	0.37	97.16
57.33	1.49	14.60	9.00	0.17	3.67	6.04	2.82	1.65	0.40	97.15

La Loma

3-LOM-T-Pit 2 tephra (20 cm)

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
56.22	1.43	13.49	8.71	0.23	3.82	7.52	2.97	1.35	0.33	96.07
55.47	1.41	14.29	9.89	0.24	4.52	8.06	2.60	1.41	0.25	98.13
54.80	1.33	14.76	8.31	0.23	5.04	9.52	3.73	0.73	0.27	98.72
54.32	1.17	16.34	6.80	0.12	4.45	9.88	4.10	0.59	0.20	97.97
53.92	1.08	16.62	7.53	0.20	4.84	10.60	3.28	0.57	0.20	98.85
53.86	1.18	15.80	8.69	0.24	4.39	9.40	3.54	0.85	0.19	98.13
53.56	1.35	16.47	9.37	0.14	3.08	8.75	4.65	0.92	0.23	98.51

Tumbiscatillo

407 (T2)

SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
58.39	2.06	14.58	7.58	0.21	1.30	5.29	4.57	1.65	0.48	96.11
56.70	1.68	14.59	9.19	0.16	3.87	7.21	4.15	0.86	0.33	98.73
56.11	1.79	14.43	8.94	0.29	3.67	6.57	3.37	1.53	0.35	97.05
55.72	1.78	14.54	9.52	0.23	3.43	7.48	3.14	1.45	0.46	97.76
55.31	1.58	14.85	9.03	0.19	3.93	7.94	4.89	0.88	0.40	98.98
54.84	1.60	13.86	9.22	0.15	4.14	7.31	3.50	1.21	0.36	96.20

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