DOI: 10.1093/gji/ggz310

Journal: Geophysical Journal International

Cite: Rodríguez-Trejo, A., Alva-Valdivia, L.M., Perrin, M., Hervé, G., & López-Valdés, N., (2019). Analysis of geomagnetic secular variation for the last 1.5 Ma recorded by volcanic rocks of the Trans Mexican Volcanic Belt: new data from Sierra de Chichinautzin, Mexico. Geophysical Journal International. volume 219, Issue 1, October 2019, Pages 594–606, Published: 10 July 2019

Geophysical Journal International

Geophys. J. Int. (2019) **219,** 594–606
doi: 10.1093/gji/ggz310
Advance Access publication 2019 July 10
GJI Geomagnetism, rock magnetism and palaeomagnetism

Analysis of geomagnetic secular variation for the last 1.5 Ma recorded by volcanic rocks of the Trans Mexican Volcanic Belt: new data from Sierra de Chichinautzin, Mexico

A. Rodríguez-Trejo,[1] L. M. Alva-Valdivia,[2] M. Perrin,[3] G. Hervé[3] and N. López-Valdés[1]

[1]*Posgrado en Ciencias de la Tierra, Instituto de Geofísica, Universidad Nacional Autónoma de México, Circuito de la Investigación Científica, C.P. 04510 México D. F., México. E-mail: alekz_igf@hotmail.com*
[2]*Laboratorio de Paleomagnetismo, Instituto de Geofísica, Universidad Nacional Autónoma de México, Circuito de la Investigación Científica, C.P. 04510 México D. F., México*
[3]*Aix Marseille Univ, CNRS, IRD, INRA, Coll France, CEREGE, Aix-en-Provence, France*

Accepted 2019 July 5. Received 2019 June 16; in original form 2019 February 7

SUMMARY

The great wealth of volcanism along the Trans Mexican Volcanic Belt (TMVB) and the need to improve the secular variation curve of the Earth magnetic field of the region is the aim of this research. 300 oriented cores from 33 sites and 21 individual cooling units were acquired from Sierra de Chichinautzin volcanic field (ChVF) and Sierra de Santa Catarina (SSC). Directional analysis and rock magnetic experiments were performed (e.g. thermal demagnetization, hysteresis loop, susceptibility *vs* temperature), achieving 21 new averaged palaeomagnetic directions. New results are consistent with the previous studies on the same cooling unit. We compiled all the palaeomagnetic studies performed on the ChVF, updating age and calculating an average direction per cooling unit and estimating an overall mean direction for the ChVF (Dec = 359.1°, Inc = 35.3°, N = 33, k = 21.6, $\alpha 95$ = 5.5°, Plat = 87.7° N, Plong = 227.4° E, K = 31.8, A95 = 4.5°).

Afterwards, we compiled all the previous palaeomagnetic studies along the whole TMVB with age ranging from 0 to 1.5 Ma, and constrained the directional analyses by specific quality criteria such as well-defined age, number of samples and quality of kappa) on the cooling unit consistency.

The mean direction and virtual geomagnetic pole (VGP) estimated for the TMVB, during the periods 0–40 ka and 0–1.5 Ma, are close to the geographic pole, supporting the validity of the geocentric axial dipole hypothesis. The directional results of this study also fit well with the predictions at Mexico City of the models SHA.DIF.14k and CALS10k2 calculated for the last 14 ka. The dispersion of the VGP's on the TMVB are also consistent with the expected values proposed by different models of palaeosecular variation. However, large gaps in the temporal record remain that should be filled by further palaeomagnetic studies.

Key words: Palaeomagnetic secular variation; Rock and mineral magnetism.

1 INTRODUCTION

The Earth's magnetic field, mainly generated in the core of the Earth, has temporal and spatial variations in direction and intensity recorded by diverse geologic materials, as volcanic rocks, archaeological materials or sediments. However, sediments that can give only relative palaeointensity estimates will not be considered here. Global models were developed using data repositories, for example MagIC (https://www2.earthref.org/MagIC) or GEOMAGIA50.v3 (Brown *et al.* 2015), to characterize the behaviour and the variation through time of the geodynamo. For the last millennia, models as CALS10k.2 and ARCH10k.1 (Constable *et al.* 2016), SHA.DIF.14k (Pavón-Carrasco *et al.* 2014) were computed by spherical harmonic analysis in space.

An accurate modelling requires a homogeneous spatial distribution of data over the globe. But the present distribution is strongly biased towards mid-latitudes of the northern hemisphere (e.g. Panovska *et al.* 2018), emphasizing the need of data from low latitudes and the Southern hemisphere. Mexico is a key area through its rich archaeological past and its intense and continuous volcanic activity for millions of years. Of particular interest, the TMVB is an active volcanic arc, characterized by thousands of volcanic structures that cross central Mexico from east to west (Fig. 1a). In the TMVB, two important volcanic fields were emplaced from

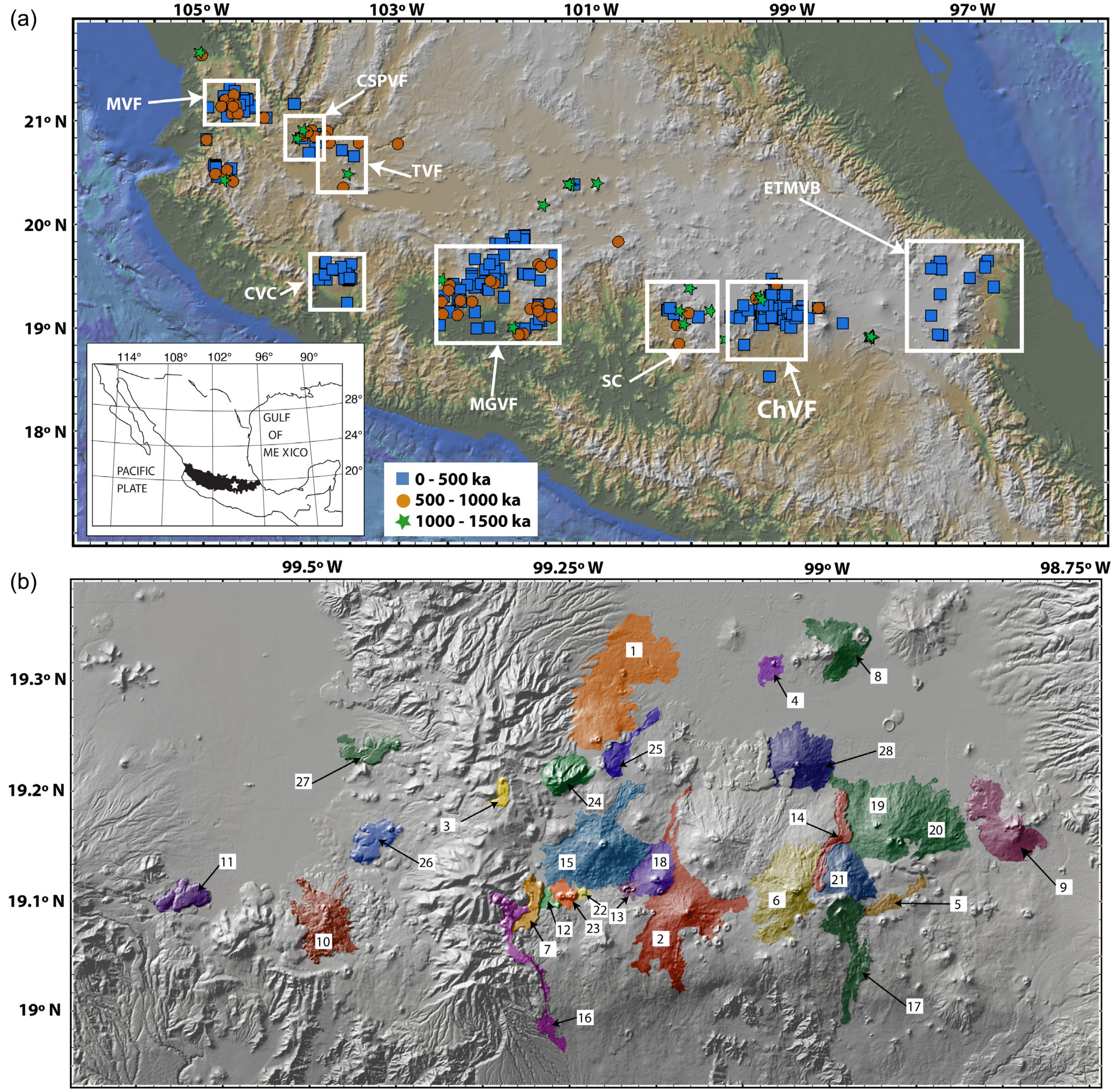

Figure 1. (a) TMVB and location of published palaeomagnetic data for the past 1.5 Ma (Satellite image from Google-earth 2018; ChVF: Sierra de Chichinautzin Volcanic Field; CSPVF: Ceboruco-San Pedro Volcanic Field; CVC: Colima Volcanic Complex; ETMVB: Eastern Trans Mexican Volcanic Belt; MGVF: Michoacán-Guanajuato Volcanic Field; MVF: Mascota Volcanic Field; SC: Sierra de las Cruces; TVF: Tequila Volcanic Field). Age references and site locations are available in Table 1S. (b) Coloured areas represent the sampled cooling units in Sierra de Chichinautzin volcanic field and Sierra de Santa Catarina monogenetic volcanic group (numbers refer to the ID of Table 1, location of the sampling sites and age references are available in Table 2; cooling units 4 and 8 belong to the Sierra de Santa Catarina (SSC) volcanic group).

late Pleistocene to Holocene: the Michoacán-Guanajuato Volcanic Field (MGVF, Fig. 1b) in west-central Mexico (e.g. González *et al.* 1997; Michalk *et al.* 2013; Mahgoub *et al.*, 2017, 2019), and the ChVF (Fig. 1b) in central Mexico. There were many palaeomagnetic studies focusing on field directions and intensities, during the last 30 yr (e.g. Herrero-Bervera & Pal 1977; Urrutia-Fucugauchi & Martin Del Pozzo 1993; Böhnel *et al.* 2003; Alva-Valdivia 2005), but new radiocarbon and Argon-Argon ages, obtained in the past 15 yr (e.g. Siebe *et al.* 2004b, Guilbaud *et al.* 2015; Jaimes-Viera *et al.* 2018) open exciting perspectives for secular variation studies.

In this work, we acquired new palaeomagnetic data from Sierra de Chichinautzin Volcanic Field (ChVF) and Sierra de Santa Catarina (SSC), which were analysed together with previous published data on rocks with well-defined age. Next, a compilation and critical analysis of the available volcanic palaeomagnetic data from the TMVB improved the understanding of the variation of the geomagnetic field during the late Pleistocene and Holocene in central Mexico.

2 GEOLOGY, CHRONOLOGY AND SAMPLING

The TMVB is a volcanic arc, 1000-km-long belt extending from the Pacific Ocean to the Gulf of Mexico, formed by subduction along the Acapulco trench, since middle Miocene (*ca*. 16 Ma) to present day (Ferrari et al., 1994, 1999). The TMVB is roughly a W–E oriented transverse belt, formed by numerous Mexican geological provinces (Ortega-Gutiérrez *et al.* 1992; Aguirre-Díaz *et al.* 1998). This geometry exposes a configuration of volcanic vents, which include abundant scoria cones grouped in extensive monogenetic volcanic fields, such as the ChVF (Fig. 1). The variations in the subduction angle of the Cocos plate, chemical assemblages, type of volcanism, change in arc width, and the existence of intraplate subduction-related alkaline volcanism, divide the TMVB into three portions: eastern, central and western (Ferrari *et al*. 2000; Gómez-Tuena *et al.* 2007). The scoria cones and related volcanic deposits studied here are part of the central TMVB. During the Pleistocene, more than 8000 volcanic structures, such as stratovolcanoes, scoria and cinder cones, were formed (Demant 1978; Aguirre-Díaz *et al.* 1998).

The ChVF, a still active hazardous volcanic field, consists of more than 220 monogenetic volcanic structures of wide compositional range. The activity started 1.6 Ma and the last eruption, the Xitle volcano, was dated at 1.6 ka BP (e.g. Martin del Pozzo 1982; Siebe *et al.* 2004a; Arce *et al.* 2013). The eruption rate was estimated around 0.016 $km^3\,ka^{-1}$ per 100 km^2 for the whole volcanic field (Arce *et al.* 2013) and around 0.6 $km^{3\,ka^{-1}}$ during the Holocene (Siebe *et al.* 2005). Close to the ChVF is located the SSC monogenetic volcanic group (units 4 and 8 in Fig. 1b) with seven volcanoes formed by lava flows and pyroclastic deposits, ranging in age from 132 to 2 ka (Jaimes-Viera *et al.* 2018).

Our palaeomagnetic sampling focused on 21 well-dated volcanic cooling units from the ChVF and SSC (Table 1). A cooling unit is defined here as a volcanic event, during which rocks were emplaced and cooled rapidly, recording almost instantaneously the Earth Magnetic Field. One up to six palaeomagnetic sites have been sampled in a given cooling unit. Ten cooling units were dated using the radiocarbon technique. The uncalibrated ages given in the original papers were carefully analyzed and updated when possible (Table 1). For example, Gonzalez *et al.* (1997) reported a ^{14}C age of 4070 ± 150 uncalibrated BP (Kirianov *et al.* 1990) for the *El Pelado* volcano but we retained only the three ages, 9620 ± 160, 10 270 ± 190 and 10 900 ± 280 uncalibrated BP, from Siebe *et al*. (2004b). All radiocarbon ages were calibrated using the most recent version of the calibration curve Intcal13 (Reimer *et al.* 2013). The age of seven others cooling units were defined using recent Argon-Argon dates (Arce *et al.* 2013; Jaimes Viera *et al.* 2018). Finally, four cooling units could not be dated more precisely than by their stratigraphic constraints with other cooling units.

The sampling was distributed in three groups: (i) the younger group of age ranging from 2 to 40 ka; (ii) the older group of age from 40 ka to 1.2 Ma, sampling volcanic structures and (iii) Sierra de Santa Catarina monogenetic volcanic group. The samples were collected *in situ*, avoiding fractured and displaced blocks. All samples were drilled directly in the field with a portable gasoline powered drill, and oriented with magnetic and sun compasses. A total of 300 cores, one inch in diameter and 6–15 cm long, were collected from 33 individual sites (8–10 cores per site) belonging to 21 cooling units along the ChVF and SSC (Fig. 1b). Cores were cut into 22-mm-long standard specimens.

3 METHODOLOGY AND LABORATORY PROCEDURES

Rock magnetic experiments were carried out in the Laboratory of Palaeomagnetism at UNAM, Mexico (except when indicated) to identify the magnetic carriers of magnetization, estimate the thermal stability of the ferromagnetic minerals during the heating processes, and characterize the domain state of the magnetic particles.

One sample per cooling unit was selected to measure the *k*-*T* curves using MFK-FA and MFK2 susceptibility-meters (Agico, Kappabridge) in UNAM and CEREGE laboratories, respectively. Specimens were heated in air from room temperature up to 620 °C.

In order to further investigate the ferromagnetic mineralogy, the hysteresis loops and acquisition of isothermal remanent magnetization (IRM) curves were acquired on small chip rocks from one sample per cooling unit using a Princeton 2900 MicroMag Alternating Gradient Magnetometer, with maximum applied fields up to 1.2 Tesla.

For the determination of the palaeomagnetic directions from the ChVF and SSC, 33 individual sites from 21 different cooling units were studied. Remanent magnetizations were measured using an AGICO JR-6 spinner magnetometer in a magnetically shielded room and analyzed by stepwise alternating field (AF) and/or thermal demagnetization on specimens from all sites. AF demagnetization was carried out on 183 specimens with a Molspin demagnetizer (Molspin Limited, England), using 10 steps up to 100 mT. Thermal demagnetization was performed on 79 specimens in a non-inductive Schönstedt furnace, with 10–12 steps every 40 °C from 100 to 600 °C.

The directions of the Characteristic Remanent Magnetization (ChRM) were estimated by principal component analysis (Kirschvink 1980), with at least five demagnetization steps and a maximum angular deviation (MAD) below 5°. As there are no report of field evidences for local tectonic movements posterior to the lava emplacement, no tectonic correction was applied.

Mean directions and VGPs were calculated at each site with Fisher statistics (Fisher 1953) and summarized in Table 2 with their $\alpha95$-confidence circle and Fisher precision parameter (k) parameters. A constant VGP latitude of 45° was used as a cutoff to discriminate the transitional values (Tauxe *et al.* 2003; Johnson *et al.* 2008; Doubrovine *et al.* 2019).

4 ROCK MAGNETISM

4.1 Susceptibility as a function of temperature (*k*–*T*)

After the *k*–*T* experiments, up to 70 per cent of the curves display two magnetic phases during the heating process and high reversibility (Fig. 2a) or a higher susceptibility for the cooling branch.

The Curie temperature range is between 510 and 540 °C for the high-temperature phase corresponding to Ti-poor titanomagnetite. The Curie temperature ranging from 230 to 300 °C, the low-temperature phase, is likely Ti-rich titanomagnetite. Two samples show highly reversible curves observed with the unique presence of Ti-poor magnetite (Figs 2c and d). The irreversible curve of El Pelado (Fig. 2b) might be related to the occurrence of Ti-maghemite

Table 1. Summary of the reported ages for ChVF and SSC, including the estimated calibrated age. The radiocarbon ages were calibrated with IntCal13 curve (Reimer *et al.* 2013) using ChronoModel software (Lanos & Philippe 2017). The average age (given in kyr BP) and its error were defined between the older and younger boundaries of the calibrated date interval at 95 per cent of confidence (2σ).

ID	Cooling unit	Calibrated age (kyrs BP)	Age error (kyrs)	Age method	Uncalibrated ^{14}C (yrs BP)	Reference
1	Xitle	1.61	0.09	^{14}C	1670 ± 35	Siebe (2000)
2	Chichinautzin	1.75	0.13	^{14}C	1835 ± 55	Siebe *et al.* (2004b)
3	Jumento	1.97	0.08	^{14}C	2010 ± 30	Arce *et al.* (2015)
4	Guadalupe	2	0.56	Ar-Ar		Jaimes-Viera *et al.* (2018)
5	Pelagatos	2.6	0.2	^{14}C	2520 ± 105	Guilbaud *et al.* (2009)
6	Tláloc	7.1	0.2	^{14}C	6200 ± 85	Siebe *et al.* (2005)
7	Tabaquillo	7	9	Ar-Ar		Jaimes-Viera *et al.* (2018)
8	Mazatepec	23	4	Ar-Ar		Jaimes-Viera *et al.* (2018)
9	Chinconquiat	>31		Stratigraphy		
10	Tres Cruces	9.4	0.3	^{14}C	8390 ± 100 8490 ± 90	Bloomfield (1975)
11	Tenango Basalt	9.5	1.0	^{14}C	8390 ± 130 8440 ± 40 8700 ± 180	Bloomfield (1974)
12	Los Cardos	<10		Stratigraphy		
13	Cima	10.1	0.6	^{14}C	10 160 ± 210 10 410 ± 80	Kirianov *et al.* (1990)
14	Tlacotenco	6.2–14		Stratigraphy		Siebe *et al.* (2005)
15	El Pelado	10.8	0.6	^{14}C	9620 ± 160 10 270 ± 190 10 900 ± 280	Siebe *et al.* (2004b)
16	Huilote	>10		Stratigraphy		
17	Cerro del Agua	12.6	0.7	^{14}C	10 845 ± 290	Guilbaud *et al.* (2015)
18	Acopiaxco	>14		Stratigraphy		Lorenzo-Merino (2016)
19	Dos Cerros 1	16.6	0.4	^{14}C	13 695 ± 110	Guilbaud *et al.* (2015)
20	Dos Cerros 2	16.6	0.6	^{14}C	13 769 ± 201	Guilbaud *et al.* (2015)
21	Cilcuayo	>18.7		Stratigraphy		
22	Raices-Cajete	18.9	0.3	^{14}C		Mahgoub *et al.* (2019)
23	Tres Cumbres	21.5	1.8	^{14}C	16 700 ± 150 19 680 ± 120	Kirianov *et al.* (1990)
24	Ajusco 1	390	160	K-Ar		Mora-Alvarez *et al.* (1991)
25	Ajusco 2	22.6	0.3	^{14}C	18 680 ± 120	Urrutia-Fucugauchi & Martin del Pozzo (1993)
26	Malinale 1	22.8	1.4	^{14}C	18 900 ± 600	Kirianov *et al.* (1990)
27	Cuautl	23.5	0.5	^{14}C	19 530 ± 160	Bloomfield (1975)
28	Tezontle	26.3	0.8	^{14}C	21 860 ± 540 21 860 ± 540	Bloomfield (1975)
29	Teuhtli	36	1.8	^{14}C	31 790 ± 755	Guilbaud *et al.* (2015)
30	Pueblo Viejo	80	20	Ar-Ar		Arce *et al.* (2013)
31	Palpan	260	20	Ar-Ar		Arce *et al.* (2013)
32	Atlacholoaya	1020	160	Ar-Ar		Arce *et al.* (2013)
33	Villa Guerrero	1200	50	Ar-Ar		Arce *et al.* (2013)

instead of Ti-magnetite, associated to mineral alteration during the heating-cooling process in the laboratory.

4.2 Hysteresis and IRM curves

The determination of saturation magnetization (M_s), saturation remanent magnetization (M_{rs}), coercive force (H_c) and remanent coercive force (H_{cr}) gave information on the domain state of the magnetic grains. With Mrs/Ms ratios between 0.1 and 0.6, and H_{cr}/H_c between 1.2 and 4.0. 80 per cent of the samples, fit in the pseudo single domain (PSD) field of the Day plot (Day *et al.* 1977), likely indicating a mixture of single domain (SD) and multidomain (MD) grains (Fig. 3b), also evidenced by the wasp-waisted shape of the 09CH007 sample (Fig. 3a). Hysteresis and IRM curves reach saturation above 800 mT, which is consistent with the presence of magnetite with different contents of titanium and the absence of high-coercivity minerals (Fig. 3).

Samples from *El Pelado* and *Chichinautzin* volcano cooling units are close to SD field and those of *Tenango* basalt and *Palpan* cone to MD field.

5 DIRECTIONAL ANALYSIS

We obtained 33 new site directions from ChVF and SSC monogenetic volcanic group: 32 sites are of normal polarity, and one (Villa Guerrero) of reverse polarity (Fig. 5a) with an age at 1200 ± 50 ka (Arce *et al.* 2013), consistent with the Matuyama chron. This is the first reversed polarity reported from the ChVF. After AF and thermal demagnetization, 80 per cent of the samples present a single component of magnetization (Figs 4a and b). The rest of the samples show a secondary component, probably of viscous origin, that could be removed at low field (less than 20 mT; Fig. 4c and d) or low temperature (less than 200 °C; Figs 4e and f). As mentioned before, no structural correction was applied to the samples, as no recent rotation or tectonic displacements were seen in the field or reported in the area in previous published studies (e.g. Herrero-Bervera & Pal 1977; Urrutia-Fucugauchi & Martin del Pozzo 1993).

Values of k and α_{95} from all sites range from 68 to 1495 and 2.7° to 8.5°, respectively, underlying the overall high precision and confidence of our mean directions.

Table 2. Summary of the directional results, where N is the number of specimens used for the calculation of the mean direction at the site level or the number of sites used for the calculation of the mean direction of the cooling unit, when there is more than six sites in a cooling unit. References: TS, This study (1) Herrero-Bervera & Pal 1977, (2) Urrutia-Fucugauchi & Martin Del Pozzo 1993, (3) González *et al.* 1997, (4) Böhnel & Molina-Garza 2002, (5) Morales *et al.* 2001, (6) Alva-Valdivia 2005, (7) Vlag *et al.* 2000, (8) Urrutia-Fucugauchi 1996, (9) Böhnel *et al.* 1997, (10) Mahgoub *et al.* 2019, (11) Mora-Alvarez *et al.* 1991.

				Location							VGP		
ID	Cooling unit	A(ge ka	Site	Lat ° N	Long ° W	N	Dec	Inc	kappa	α_{95}	Plat ° N	Plong ° E	Ref
1	Xitle	1.61 ± 0.09	6	19.300	99.200	17	358	34	301	2.1	88	152	1
			7	19.300	99.200	11	355	34	86	5.0	85	164	1
			11	19.300	99.200	12	16	36	230	2.9	75	346	1
			13	19.300	99.200	8	355	39	114	5.2	85	202	1
			14	19.300	99.200	8	357	52	151	4.5	76	250	1
			15	19.300	99.200	7	356	34	62	7.7	86	162	1
			XT-1	19.180	99.100	6	357	32	276	4.0	87	139	2
			S-9	19.320	99.180	9	350	35	663	2.0	81	172	3
			Xitle	19.190	99.110	15	347	36	521	1.7	78	177	9
			JM	19.320	99.187	13	352	36	269	2.5	82	177	5
			Flow 1	19.315	99.174	9	4	32	87	5.6	86	18	6
			Flow 2	19.315	99.174	8	0	35	351	3.0	90	81	6
			Flow 3	19.315	99.174	10	2	34	131	4.2	88	10	6
			Flow 4	19.315	99.174	10	3	32	156	3.9	87	25	6
			Flow 5	19.315	99.174	8	3	35	72	6.6	87	351	6
			Flow 6	19.315	99.174	9	356	30	309	2.9	85	131	6
			Flow 7	19.315	99.174	9	5	36	280	3.1	85	342	6
			Flow 8*	19.315	99.174	8	359	33	57	7.4	88	117	6
			Xite	19.36	99.17	113	1	34	263	0.8	89	28	4
			Xitle CU-1	19.35	99.13	6	357	34.9	477	3.1	86	17	8
			Xitle CU-2	19.36	99.15	6	353.6	36.2	151	4.5	84	178	8
			Xitle XT-6	19.25	99.26	9	355	37	123	4.7	85	188	8
			Xitle *P*-8	19.33	99.15	8	356	30	67	6.8	85	131	8
			Average			**23**	**358**	**35**	**159**	**2.4**	**88**	**173**	
2	Chichinautzin	1.75 ± 0.13	CH-1	19.091	99.080	7	357	30	91	9.7	86	125	TS
			CH-2	19.119	99.126	8	3	30	214	6.3	86	37	TS
			CH-IV	19.105	99.161	8	349	32	181	5.7	79	163	TS
			PL-CH1	19.116	99.147	8	354	34	953	3.0	84	167	TS
			CH-I	19.107	99.156	7	357	40	153	6.2	85	224	TS
			1	19.100	99.100	8	358	27	73	6.5	85	103	1
			GU-PI	19.020	99.140	23	3	34	98	3.1	87	1	10
			Average			**6**	**357**	**32**	**190**	**4.4**	**86**	**147**	
3	Jumento	1.97 ± 0.08	Jumento	19.206	99.315	16	349	50	233	4.4	75	222	TS
			El Jumento—B*	19.187	99.320	25	354	32	52	4.1	84	156	10
4	Guadalupe	2 ± 0.56	SC1	19.323	99.023	8	9	37	85	6.0	81	341	TS
5	Pelagatos	2.6 ± 0.2	MMA-23-A	19.117	98.910	8	1	27	1459	2.4	85	72	TS
			A2	19.103	98.934	8	3	20	618	3.7	80	61	TS
			Average			**16**	**2**	**23**	**212**	**3.4**	**82**	**66**	
6	Tláloc	7.1 ± 0.2	A5	19.140	99.008	7	2	10	180	6.9	76	73	TS
7	Tabaquillo	7 ± 9	Tabaquillo	19.119	99.291	8	360	44	1141	2.7	83	261	TS
8	Mazatepec	23 ± 4	SSC2	19.317	99.036	8	357	34	149	6.3	87	158	TS
9	Chinconquiat	>31	A3	19.207	98.859	8	349	21	209	8.5	77	135	TS
10	Tres Cruces	9.4 ± 0.3	Site 1 + 2	19.103	99.502	16	339	50	196	3.7	68	206	7
			S-6	19.12	99.49	7	337	56	463	3.1	63	216	3
11	Tenango	9.5 ± 1	TEO-Alto	19.110	99.596	8	358	65	163	7.2	62	257	TS
			TEO-Bajo	19.110	99.596	7	3	71	315	5.2	53	263	TS
			Average			**15**	**1**	**68**	**137**	**4.8**	**58**	**262**	
			Tenango1	19.0895	99.6258	10	18	36	99	4.9	73	344	10
12	Los Cardos	<10	Cardos	19.094	99.260	8	356	39	96	5.6	85	210	TS
13	Cima	10.1 ± 0.6	12*	19.100	99.200	13	6	16	21	9.2	78	52	1
			Cima 2	19.100	99.190	7	17	22	71	7.2	72	14	2
			Cima 3	19.100	99.170	7	355	41	139	5.1	84	215	3
14	Tlacotenco	10.2 ± 3.8	MMA-25-A	19.153	98.983	8	12	12	253	5.8	72	39	TS
			MMA-C	19.161	98.991	7	3	4	238	5.0	73	71	TS
			Average			**15**	**5**	**7**	**143**	**4.3**	**73**	**63**	
15	El Pelado*	10.8 ± 0.6	SITIO D	19.142	99.169	8	14	22	112	6.4	75	19	TS
			SITIO A	19.116	99.268	6	358	38	79	8.7	87	213	TS
			SITIO B	19.120	99.274	8	347	29	124	6.0	77	156	TS
			SITIO C	19.123	99.277	6	359	38	68	10.5	87	235	TS
			PL-02	19.120	99.260	8	354	34	954	3.0	85	165	TS
			PL-01	19.137	99.255	8	12	22	121	5.4	77	23	TS

Table 2. Continued

				Location							VGP		
ID	Cooling unit	A(ge ka	Site	Lat ° N	Long ° W	N	Dec	Inc	kappa	α_{95}	Plat ° N	Plong ° E	Ref
			Average			**44**	**0**	**31**	**48**	**6.7**	**87**	**81**	
			8*	19.200	99.200	9	7	33	51	7.3	83	1	1
			9	19.200	99.200	8	5	27	115	5.2	83	36	1
			10	19.200	99.200	9	6	35	118	4.8	84	349	1
			P-2	19.150	99.210	6	355	15	130	5.9	78	104	2
			S-10	19.140	101.420	7	352	12	60	7.9	75	110	3
			JB	19.186	99.169	8	10	17	198	3.9	76	37	5
			PEL I –II	19.120	99.190	12	18	18	115	4.1	70	18	10
			Average			**7**	**5**	**23**	**43**	**9.3**	**83**	**66**	
16	Huilote	>10	Huilote 1	19.034	99.270	8	14	11	353	3.0	71	34	5
			Huilote 2	19.034	99.304	8	4	23	277	3.3	82	52	5
17	Cerro del Agua	12.6 ± 0.7	A4	19.008	98.985	8	5	17	187	5.6	79	55	TS
18	Acopiaxco	>14	JJ	19.110	99.176	13	353	33	498	1.9	83	162	5
19	Dos Cerros 1	16.6 ± 0.4	MMA-46	19.117	98.910	8	2	50	154	6.2	78	270	TS
20	Dos Cerros 2	16.6 ± 0.6	MMA-44	19.156	98.869	8	10	45	174	5.1	78	311	TS
		16.6 ± 0.6	DCR	19.156	98.868	15	345	48	209	2.7	73	211	10
21	Cilcuayo	>18.7	MMA-79B	19.139	98.971	8	358	20	223	6.2	81	94	TS
22	Raices-Cajete	18.9 ± 0.3	PI3	19.1058	99.2406	6	359	47	194	4.8	81	255	10
23	Tres Cumbres	21.5 ± 1.8	TC-5	19.100	99.260	6	3	22	317	3.8	82	60	2
24	Ajusco*	390 ± 160	JH	19.19	99.25	8	343	22	371	2.9	72	148	5
			C3-B Ajusco	19.43	99.13	14	0	17	18	9.9	79	81	11
			C3-A Ajusco	19.43	99.13	13	124	0	111	3.8	-32	338	11
		22.6 ± 0.3	JL	19.22	99.27	10	359	45	131	4.2	83	254	5
25	Malinale	22.8 ± 1.4	Malinale 1	19.210	99.210	6	6	33	513	3.0	84	2	2
			S-3	19.220	99.210	5	359	34	175	5.8	89	139	3
26	Cuautl	23.5 ± 0.5	S-7	19.170	99.420	6	343	17	255	4.2	71	141	3
27	Tezontle	26.3 ± 0.8	S-5	19.220	99.470	7	353	64	318	3.4	63	250	3
28	Teuhtli	36 ± 1.8	A1	19.162	98.991	8	353	31	119	8.5	83	152	TS
			5	19.200	99.020	11	345	19	118	4.2	73	140	1
			THT	19.244	99.054	8	355.7	26.5	1066.25	1.7	83.3	120	10
29	Pueblo Viejo	80 ± 20	AT-3	18.527	99.197	8	357	57	636	3.6	71	254	TS
30	Palpan	260 ± 20	PA-05	18.843	99.460	8	354	24	387	4.7	82	124	TS
31	Atlacholoaya	1020 ± 160	AT-1	18.689	99.233	8	3	58	227	6.1	70	268	TS
32	Villa Guerrero	1200 ± 50	SH-06	18.894	99.645	7	178	-34	1495	3.2	-88	343	TS

+Mean direction estimated at site level.

*Sites that do not fulfill our selection criteria were discarded for the calculation of mean directions.

The cooling units were divided into two groups according to their ages: (i) the younger group of 17 out of the 21 sampled cooling units with ages ranging from 1.7 to 40 ka and (ii) the older group of 4 out of the 21 cooling units with ages ranging from 80 ka to 1.2 Ma. The mean direction associated to the younger group (Dec = 359.7°, Inc = 33.1°, N = 16, k = 22.8, $\alpha_{95} = 7.1°$, Plat = 89.6° N, Plong = 205.1° E, K = 37.6, $A_{95} = 6.1$), is consistent with the direction of the dipole field (at the average site latitude). The precision interval of K with the 95 per cent confidence (Cox 1969) are ranging from $25 < K < 50$. For this estimation, one cooling unit (El Pelado) was discarded for the calculation, because it did not fulfill our selection criteria. The mean direction associated to the older group (Dec = 357.9°, Inc = 49°, N = 4, k = 28.2, $\alpha_{95} = 19.2$, Plat = 73.1° N, Plong = 253.8° E, K = 38.8, $A_{95} = 23.8$) is pretty similar with a scatter likely related to a larger time interval with only four cooling units available. However, the precision interval of K with the 95 per cent confidence (Cox 1969) is ranging from $6 < K < 39$, that is statistically indistinguishable with the younger group. The dispersion of the VGP estimated for this study ($S_b = 13.4$) fits with the expected value for the latitude (*ca*. 20°) according with the Model G (McFadden *et al.* 1991), and with the projections from different data sets at similar latitudes (e.g. Johnson *et al.* 2008; Opdyke *et al.* 2015; Cromwell *et al.* 2018).

6 COMPARISON WITH PREVIOUS PUBLISHED DATA FROM ChVF

The ChVF has been previously studied reported by twelve palaeomagnetic studies (Herrero-Bervera & Pal 1977; Mora-Alvarez *et al.* 1991; Urrutia-Fucugauchi & Martin del Pozzo 1993; Mooser *et al.* 19741994; Urrutia-Fucugauchi 1996; Böhnel *et al.* 1997; Gonzalez *et al.* 1997; Vlag *et al.* 2000; Morales *et al.* 2001; Böhnel & Molina-Garza 2002; Alva-Valdivia 2005; Maghoub *et al*. 2019) for rocks younger than 40 ka. One of these papers (Mooser *et al.* 1974) was not included in the analysis because important information as the sampling location, age and demagnetization protocols were not given in the publication.

A crucial aspect of such a compilation is the quality of the ages attributed to the different data. When possible, the ages given in the original papers were updated (Table 1). Because it was not possible to attribute them a reliable absolute age, the mean results of *Ajusco* (Morales *et al.* 2001) and the site CH-45 (Urrutia-Fucugauchi & Martin Del Pozzo 1993) had to be discarded. Similar problem occurs with the ages of *Acopiaxco* and *Huilote* from Morales *et al.* (2001), but a relative age could be estimated by stratigraphy according to recent published data, supported by direct observations in the field. Only updated ages by cooling unit are given in Tables 1 and 2.

According to their location and reported age, the previous pub-

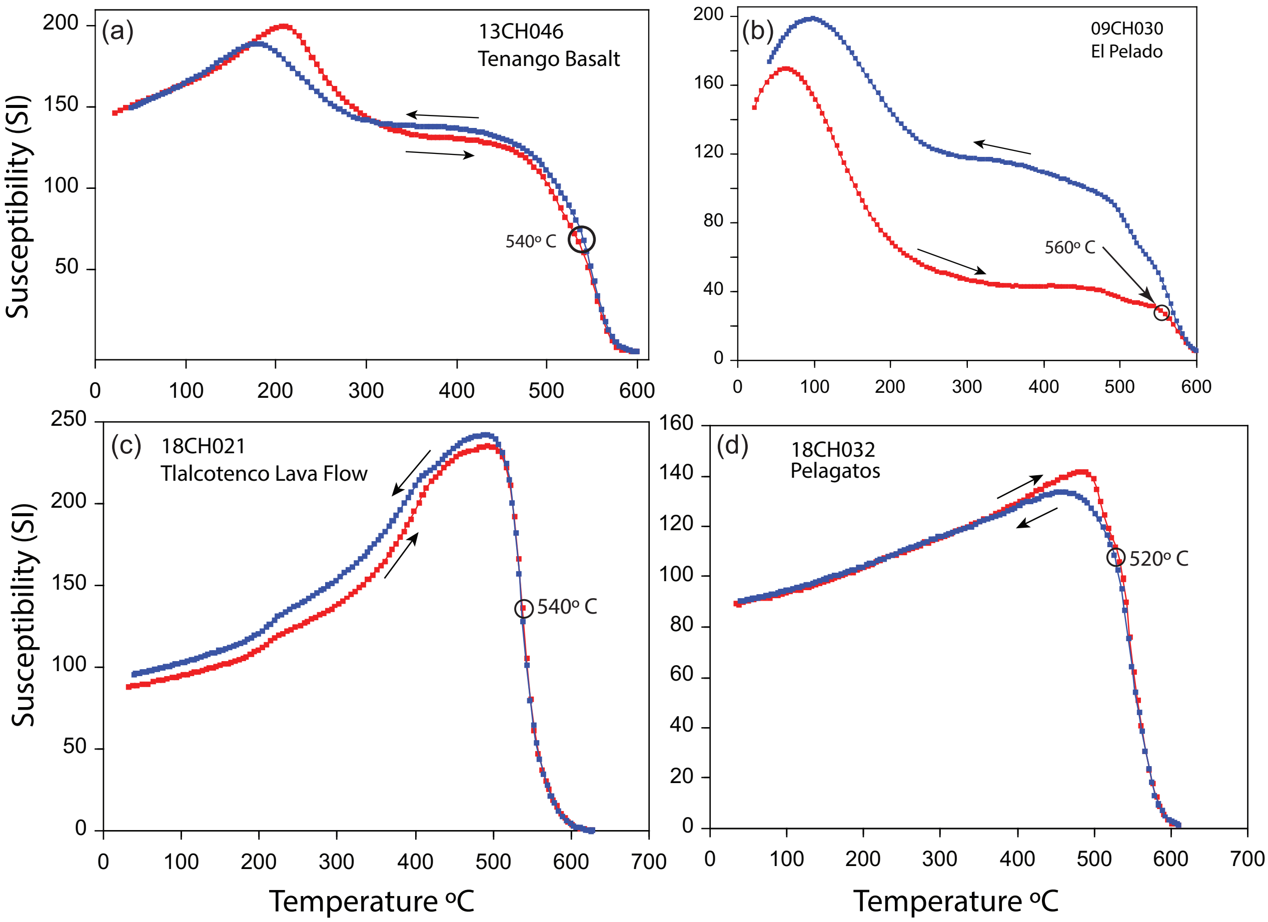

Figure 2. Representative heating (red) and cooling (blue) susceptibility *vs* temperature curves.

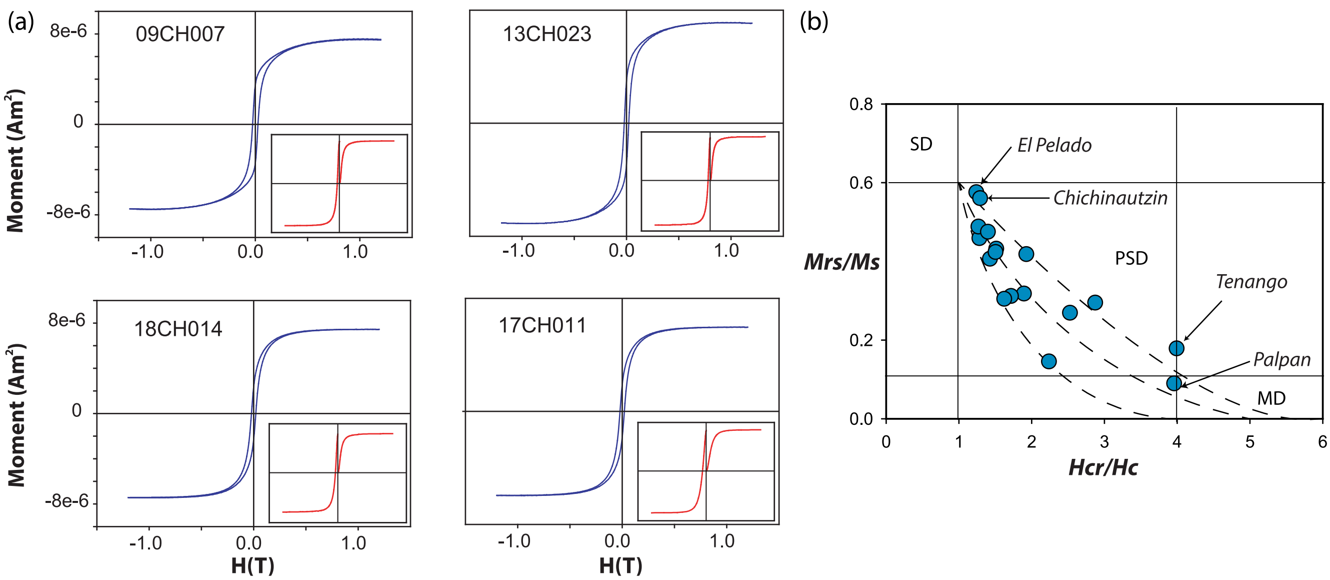

Figure 3. (a) Representative hysteresis plots in blue and IRM acquisition and backfield curves in red. Paramagnetic components are removed. (b) Day plot from ChVF and SSC samples with SD-MD mixing curves of Dunlop (2002).

lished mean directions have been allocated to the different ChVF's cooling units (Fig. 1b, Table 2). When different publications report data from the same cooling unit, as for *Xitle* and *El Pelado* volcanoes, we calculate a mean direction at the cooling unit level (Table 2). For the special case of El Pelado volcano, two means are available: a mean estimated at sample level obtained from 44 samples demagnetized in this study obtained for different locations of the volcano; and a mean calculated at site level from 6 sites reported

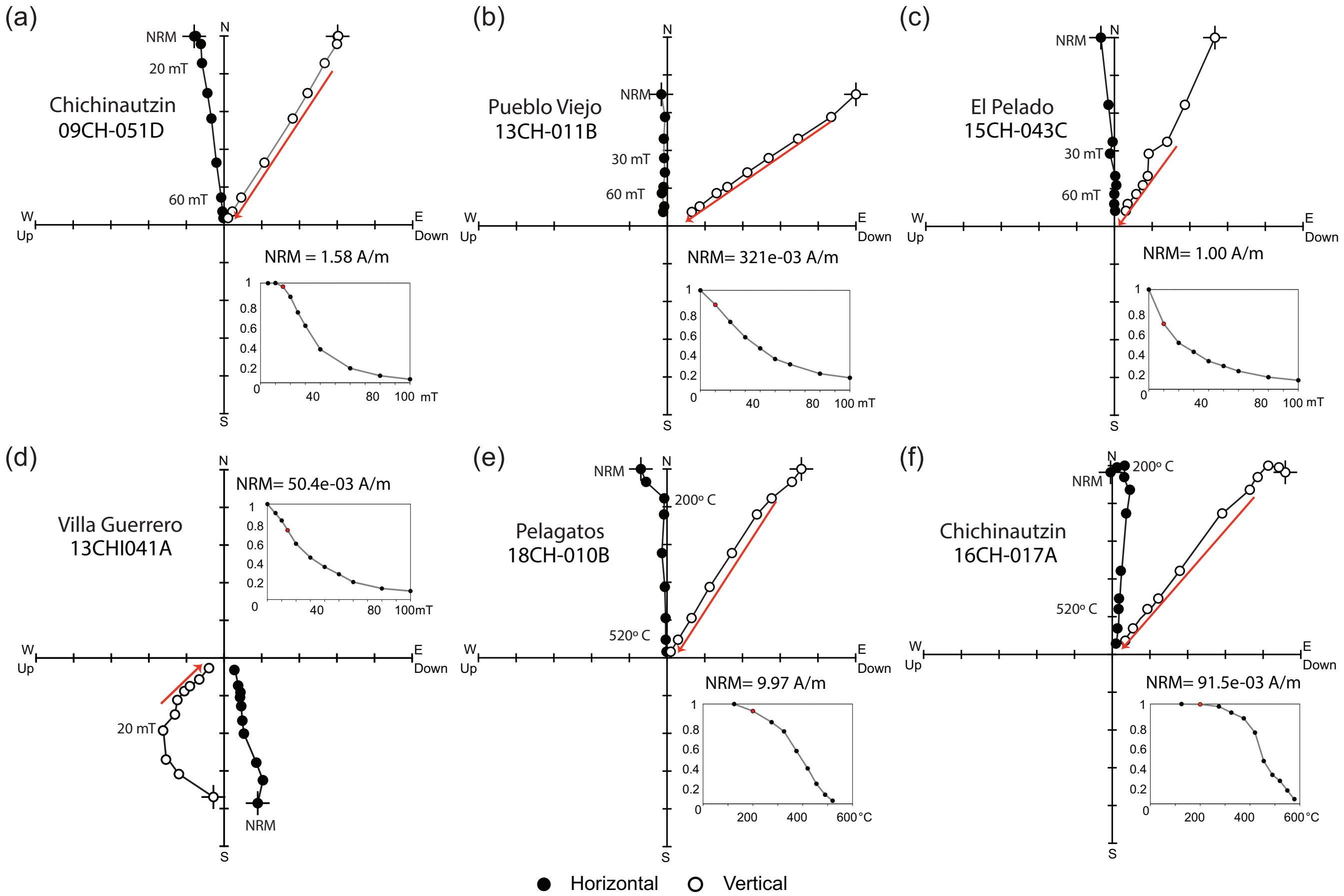

Figure 4. Representative orthogonal plots and demagnetization curves of AF (a–d) and thermal (e–f) demagnetization. Solid (open) circles are the projection on the horizontal (vertical) plane. Red line indicates the number of points selected for the ChRM calculation.

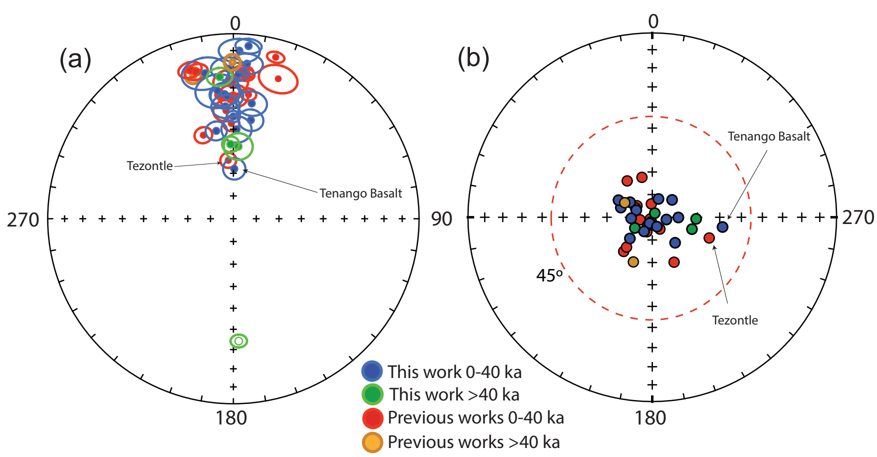

Figure 5. Equal area projection of the mean directions (left) and distribution of the VGP's (right) per cooling unit of the ChVF.

from previous works in El Pelado, details available in Table 2. For the previous published data, when more than two sites were available for a given CU, the mean was calculated at site level. When only two sites were available no average was provided, such as Cima volcano, with three sites available, but one of them were discarded. All the mean directions estimated for a given cooling units in this study were calculated at sample level. In order to assure similar quality between our data and the previously published palaeomagnetic data, we defined some minimum quality criteria: at least four specimens are required to obtain a mean direction for each cooling unit, and cut off value for *k* parameter larger than 60 (e.g. Johnson *et al.* 2008; Cromwell *et al.* 2018). This value was determined from the statistical analysis of the directional data compilation from the TMVB on the past 1.5 Ma (Fig. 6) and approaching within 95 per cent confidence of the distribution of the data (ca. 2σ).

A special case is the *Tenango* basalt, located on the western side of the ChVF, of 8.5 ± 0.16 ka (Bloomfield 1974), that presents high value of inclination (68.2°), atypical for this period and at

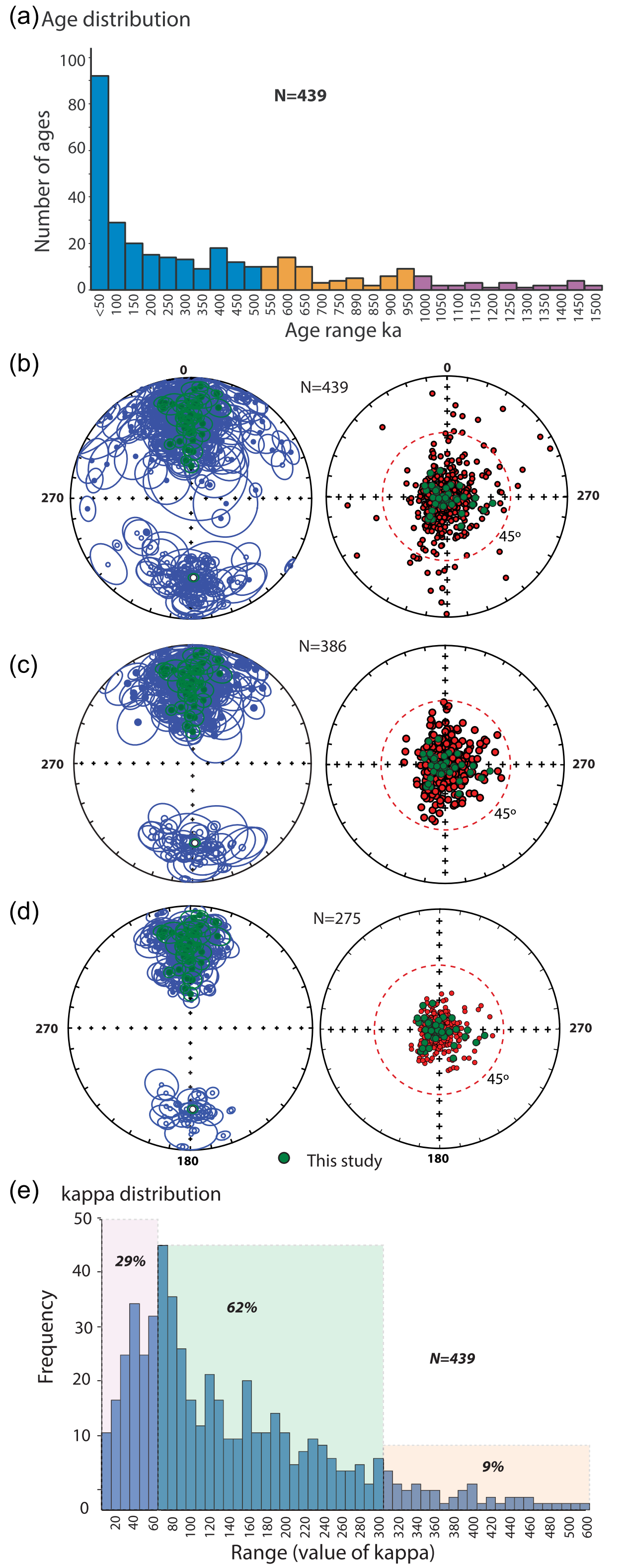

Figure 6. Directional relocated data and VGP. (a) Age distribution; (b) all the data in the compilation; (c) after removing data disturbed, transitional or with age problem; (d) after applying quality criteria; (e) distribution of k for the palaeomagnetic directions of the TMVB for the last 1.5 Ma. Full data set available in Table 1S.

this latitude. Gonzalez *et al.* (1997) report a similar value for the *Tezontle* volcano (21.8 ± 38 Ka, Bloomfield 1975), located at the southwestern part of the ChVF. Finally, other two cooling units present similar high inclination values: *Pueblo Viejo* lava flow and *Atlacholoaya* scoria cone, both cooling units being located at the southwestern boundary of the volcanic field, but belonging to the older group of the ChVF > 40 ka (Arce *et al.* 2013). On the other side, the cooling unit *Tláloc*, 7.1 ± 0.2 ka, and the *Tlalcotenco* lava flow, 6.4–14 ka, (Siebe *et al.* 2005) present atypical low inclination value of 10° and 7°, respectively (Table 2). None of these directions can be considered as transitional because they are inside the 45° cut-off (Johnson *et al.* 2008; Cromwell *et al.* 2018) to differentiate transitional polarities (Fig. 5b). According to the statistical quality of the mean directions, there is no objective reason to discard these sites, and they have been included in the mean calculations.

All selected mean directions per cooling unit are presented with their α_{95} confidence circle in Fig. 5(a), and the associated VGP's in Fig. 5(b). An overall mean was estimated for the last 40 ka (Dec = 359.1°, Inc = 34.1°, N = 30, k = 22.2, α_{95} = 5.7°, Plat = 88.6° N, Plong = 208.6° E, K = 32.4, A_{95} = 4.7°). This average is similar to the mean direction that was calculated with our samples, and consistent with the expected value of the actual dipole. The 33 available cooling units for the ChVF and SSC were used to calculate the mean for the last 1.5 Ma (Dec = 359.1°, Inc = 35.3°, N = 33, k = 21.6, α_{95} = 5.5°, Plat = 87.7° N, Plong = 227.4° E, K = 31.8, A_{95} = 4.5°) that remains very close to the geographic pole. The overall dispersion of the VGP's estimated (S_b = 14.37) of the previous published data combined with the new data set from this study match (Fig. 8) with the predicted value of the Model G (McFadden *et al.* 1991) and with the curves of latitude dependence of VGP scatter published recently (e.g. Johnson *et al.* 2008; Opdyke *et al.* 2015; Cromwell *et al.* 2018), showing an accurately average secular variation recorded from the ChVF lavas.

7 THE TMVB PALAEOMAGNETIC DATA SET AND THE TIME AVERAGED DIPOLE FIELD FOR THE LAST 1.5 Ma

The Trans Mexican volcanic belt has been active since the last 12 Ma. However, we restricted our compilation to the last 1.5 Ma, the period for which we have most of the palaeomagnetic studies. 48 publications (Table 1S) were retrieved for this period, most of them are fairly recent (72 per cent of the articles were published in the 2000s), and only a few were published in the 1970s. 30 per cent of the data have an age lower than 50 ka, 20 per cent of the data have ages between 50 and 250 ka, and no trend can be seen between the age distribution and the location (Table 1S).

Around 70 per cent of the previous palaeomagnetic data come from the central part of the TMVB: Michoacán-Guanajuato volcanic field (MGVF); Sierra de la Cruces (SC) and ChVF (Fig. 1b). The latitudes of the data are fairly similar (between 18.2°N and 21.7°N), but the longitudes vary a lot more (from 96.5°W to 106°W) covering about 1000 km from east to west. Therefore, to consider these differences in longitude (up to 10°), all compiled directions (Table 1S) were relocated to a common geographic place, arbitrarily chosen at Zócalo downtown in Mexico City (19.4327°N and 99.1332°W).

Altogether 439 individual sites were compiled (Fig. 6b, Table 1S). All data that have been identified by the original authors as remagnetized units, affected by lightning or local tectonics and displaced blocks, or were not considered in the analysis, and are labelled as *disturbed* in Table 1S. Using a 45° cut-off for transitional VGP's,

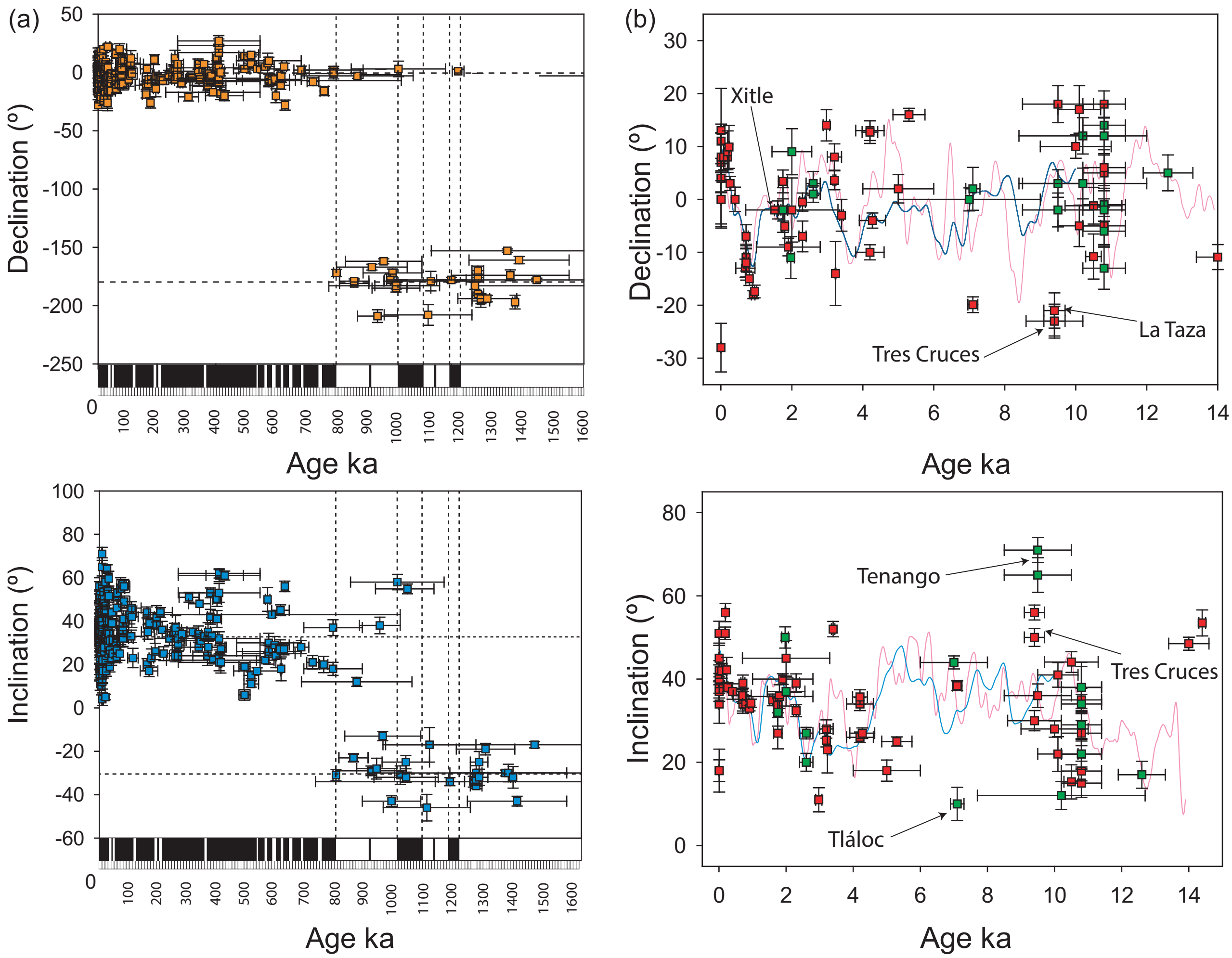

Figure 7. a) Distribution of the declination and inclination parameters on the TMVB for the past 1.5 Ma. b) Data from the past 14 ka from ChVF (green squares) and the TMVB (red squares) with the models SHA.DIF.14k (red line) and CALS10k2 (blue line).

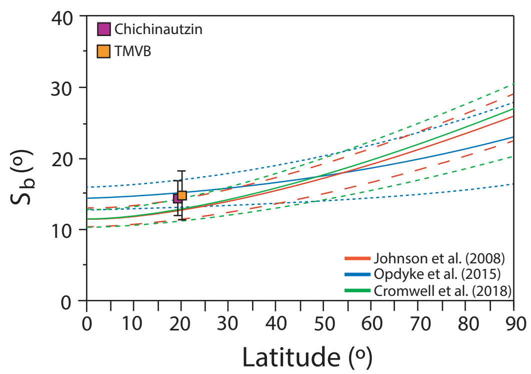

Figure 8. Latitude dependence of the VGP's for the last 5 Ma (Johnson *et al.* 2008 and Opdyke *et al.* 2015) and for the last 10 Ma (Cromwell *et al.* 2018). Modified from, Doubrovine *et al.* (2019).

some other data (labelled as *transitional* in Table 1S) were also discarded. The same care was paid to the age of the determination and a certain number of the data were discarded because of imprecision or absence of age (labelled as *age* in Table 1S). After applying these three basic criteria, *ca*. 29 per cent of the data (Fig. 6c) were removed. Finally, the quality criteria used to select the ChVF data ($N \geq 4$ and $k > 60$) were applied to the TMVB data (Fig. 6d). The distribution of k in the published data is summarized in Fig. 6(e), with 29 per cent of the data below the chosen value of 60, 61 per cent of the data having k ranging from 60 to 300, and 9 per cent of the data with very high-quality value over 300.

An overall mean direction and pole were estimated with the selected palaeomagnetic data set, including the new results from ChVF and SSC. Mean directions were estimated for both normal and reverse polarities, (Dec = 358.4°, Inc = 35°, N = 245, k = 31.7, α_{95} = 1.5°) and (Dec = 180.6°, Inc = -30.1°, N = 25, k = 32.5, α_{95} = 5.2°), respectively. The reversal test (McFadden & McElhinny 1990) is positive with a difference of ∼3° between the reversal and normal polarities, supporting the reliability of the selected data set. The combined mean direction, calculated for the past 1.5 Ma of the TMVB (Dec = 358.4°, Inc = 35°, N = 275, k = 31.7, α_{95} = 1.6°) with its corresponding VGP (Plat = 88.3° N, Plong = 188.6° E, K = 40.2, A_{95} = 1.4°), is therefore very robust and strongly support the reliability of the Geocentric Axial Dipole hypothesis.

Mexico is indeed characterized by a very active tectonic setting, especially on the west coast with the subduction of the Cocos Plate beneath the North American Plate along the Acapulco trench. The tectonics activity, considered active in the present days make possible local displacements and vertical axis rotations (e.g. Alva-Valdivia *et al.* 2017, 2019), with low influence in the general setting of all the TMVB. However, if this active tectonic was clearly the trigger of the volcanic activity in central México (Gomez-Tuena *et al.* 2007), no large movement that would have disturbed the TMVB directions could be detected, at least for the last 1.5 Ma. The major tectonic movements along the TMVB were reported for the older activity during the Miocene (Alva-Valdivia *et al.* 2000). It is possible that for the younger activity some areas could be affected by regional tectonic activity, generating tilts and/or vertical axis rotations, the data reported from the authors as tectonically disturbed were no considered for this study. The unrecognized tectonic activity in the area that was not reported by the authors is not possible to observe directly, but the accuracy and precision of the date is supported by the statistical parameters published. The palaeosecular variation (PSV) recorded by the volcanic rocks of the TMVB show that latitude dependence of dispersion of the combined polarities of the VGP's estimated for all the data set in this work ($S_b = 14.6$), show that matches with the different models (e.g. Johnson *et al.* 2008; Opdyke *et al.* 2015; Cromwell *et al.* 2018) at the mean latitude of the TMVB (*ca*. 20°). After discarding the disturbed data from the selection criteria, is possible to determine that the TMVB has a reliable record of the PSV for the last 1.5 Ma. The dispersion of the VGP's show that the local tectonic activity doesn't affect considerably to the mean values estimated in this study (Fig. 8). As reported by Opdyke *et al.* (2015), results from lower latitudes show disturbances on the S_b due to the intense activity recorded.

Looking at the evolution of relocated declination and inclination through time, we can see that the Brunhes normal chron (0–781 ka) is well recorded in the TMVB data set (Fig. 7a). It is not the same for the Matuyama reverse chron (781–2581 ka), especially during the first reverse subchron (C1r.1r, 781–988 ka) that presents almost as many normal polarity data as reverse polarity data (Fig. 7a). Part of this dispersion is probably due to age uncertainty, but may also be related to undetected remagnetizations in a recent normal field. While the Jaramillo subchron (988–1072 ka) is accurately recorded, the Cobb subchron (1173–1185 ka) is not represented in the TMVB data set.

8 SECULAR VARIATION RECORDED IN THE TMVB

Considering the limitations of the available data set, we concentrate on a more recent period, for which we have the larger number of studies, *ca*. 34 per cent of the full data set compiled to study the secular variation: the last 14 millennia (Fig. 7b).

For the last 4 millennia, the TMVB results are consistent with the predictions at Mexico City of two recent global models: CALS10k2 (Constable *et al.* 2016) and SHA.DIF.14k (Pavón-Carrasco *et al.* 2014). This result is not surprising as most data considered in this analysis were included in the calculation of these models. During the last four millennia, declination varied between –20° and 20° and inclination varied between 15° and 60°.

For earlier periods, the gaps in the database, especially between 5000 and 8000 BP and beyond 11 000 BP, prevent an accurate recovery of the secular variation. The range of directions between 9000 and 11 000 BP suggests a larger and faster secular variation than predicted by the global models. High inclination values up to 68° and low declination values up to –30° were observed in Tenango, la Taza and Tres Cruces cooling units (Fig. 7b). More data are required to better constrain this large variation and understand its geomagnetic origin.

8.1 Dispersion of the VGP's

During the last years, different compilations of directional data from different latitudes around the world, including Mexico were performed (e.g. Johnson *et al.* 2008; Opdyke *et al.* 2015; Cromwell *et al.* 2018; Doubrovine *et al.* 2019). The objective is to assembly the record of the PSV at different intervals of time at different latitudes, showing the dependence of the dispersion of the VGP scatter with the latitude. In this work the dispersion of the VGP was estimated for the ChVF data, and for the data set compiled for the TMVB, to verify the record of the concordance with the Model G (McFadden *et al.* 1991) and with the compilations proposed for the past 0–5 Ma and 0–10 Ma. For Mexico, with a latitude *ca*. 20°, different works estimate the PSV by the VGP scatter for 0–5 Ma. Mejia *et al.* (2005) estimate the VGP scatter ($S_b = 12.7°$) for the TMVB by selecting 187 sites, and found equivalence with the expected value from Model G ($S_b = 13.5°$). Later, Ruiz-Martinez *et al.* (2000) with 77 selected sites, estimated the dispersion of the VGP ($S_F = 14.8°$) and compared the fit with the Model G and the model that use a data set from Mexico ($S_b = 14.3$) proposed by Johnson *et al.* (2008). In this study, we compare the VGP scatter estimated for ChVF ($S_b = 14.4$) and for the entire compilation of TMVB ($S_b = 14.6$), with the results of three global compilations that uses different results from Mexico from 0 to 5 Ma and from 0 to 10 Ma (Cromwell *et al.* 2018). Fig. 8 shows the correspondence of the results from this study with the expected values according with the three models. In the case of Cromwell *et al.* (2018), is possible to observe a slight lower S_b value, in comparison with the results from the TMVB. This small difference could be associated to a higher average of the model (0–10 Ma). However, in all cases, the results estimated for ChVF and TMVB fit with the expected value of the S_b according to the latitude. This concurrence, supports the hypothesis that the local tectonic activity in the TMVB does not affect significantly the average estimated for the last 1.5 Ma.

9 CONCLUSIONS

The ferromagnetic mineralogy of the ChVF and SSC volcanic groups is dominated by titanomagnetite with different contents in titanium and Curie temperatures ranging from 230 to 540 °C. The magnetic domain state is a mixture of single and multidomain grains.

The directional analysis of the cooling units shows that the mean direction and VGP obtained for the last 40 ka for ChVF are: (Dec = 359.1°, Inc = 34.1°, N = 30, k = 22.2, $\alpha95 = 5.7°$); and (Plat = 88.6° N, Plong = 208.6° E, K = 32.4, $A_{95} = 4.7°$), respectively. These values are close to the present GAD value. The directional results of this study also fit well with the predictions in Mexico City of the global models SHA.DIF.14k and CALS10k2 but only a few data are available from 5 to 9 ka, and study of other structures formed in this time range will be necessary to improve the accuracy of the curves. Similarly, the mean direction and corresponding VGP for the past 1.5 Ma are: (Dec = 359.1°, Inc = 35.3°, N = 33, k = 21.6, $\alpha95 = 5.5°$); and (Plat = 87.7° N, Plong = 227.4° E, K = 31.8, A95 = 4.5°), respectively, also consistent with the expected GAD value in this period. A reversed polarity dated at 1020 ± 160 (Arce *et al.* 2013) was found, and this is the first geomagnetic reversal recorded by the ChVF.

The mean directions from ChVF and SSC are consistent with the mean directional data recorded in volcanic rocks for all published data from the TMVB (Dec = 358.4°, Inc = 35°, N = 275, k = 31.7, $\alpha_{95} = 1.4°$) with its corresponding VGP (Plat = 88.3°

N, Plong = 188.6° E, K = 40.2, A_{95} = 1.4°). The selection criteria allowed identify the highest quality data to describe the evolution of the time average dipole field, and to constrain the results that will give the most reliable mean directions and VGPs. The directional results and the VGP's scatter (Fig. 8) fit with the expected values according with the latitude of the TMVB, proposed by different global compilations (Johnson *et al.* 2008; Opdyke *et al.* 2015; Cromwell *et al.* 2018). The concordance confirms that the TMVB has not been affected considerably by local tectonics in the past 1.5 Ma. However, large gaps remain in the temporal record of the TMVB that should be filled by further palaeomagnetic studies.

ACKNOWLEDGEMENTS

We appreciate the financial support to LMAV from PAPIIT-DGAPA-UNAM IN113117 (Mexico), to LMAV and MP from the ANR-CONACyT (France-Mexico) 273564 research projects. GH was supported by Campus France PRESTIGE program (PRESTIGE-2017-1-0002). Thanks to J. A. González Rangel, M. Espinosa, V. Macias and François Demory for their support in the laboratories. The authors would like to thank Dr. A. Biggin (editor), Dr. P. Doubrovine and an anonymous reviewer for their comments.

REFERENCES

Aguirre-Diaz, G.J., Ferrari, L., Nelson, S.A., Carrasco-Núnez, G., Lopez-Martinez, M. & Urrutia-Fucugauchi, J., 1998. El cinturón volcánico mexicano: un nuevo proyecto multidisciplinario.

Alva-Valdivia, L.M., Goguitchaichvili, A., Ferrari, L., Rosas-Elguera, J., Urrutia-Fucugauchi, J. & Zamorano-Orozco, J.J., 2000. Palaeomagnetic data from the Trans-Mexican Volcanic Belt, *Earth, Planets Space,* **52**(7), 467–478.

Alva-Valdivia, L.M., 2005. Comprehensive paleomagnetic study of a succession of Holocene olivine-basalt flow: Xitle Volcano (Mexico) revisited, *Earth, Planets Space,* **57**(9), 839–853.

Alva-Valdivia, L.M., Agarwal, A., Caballero-Miranda, C., García-Amador, B.I., Morales-Barrera, W., Rodríguez-Elizarraráz, S. & Rodríguez-Trejo, A., 2017. Paleomagnetic and AMS studies of the El Castillo ignimbrite, central-east Mexico: source and rock magnetic nature, *J. Volc. Geotherm. Res.,* **336,** 140–154.

Alva-Valdivia, L.M., Agarwal, A., García-Amador, B., Morales-Barrera, W., Agarwal, K.K., Rodríguez, S. & Gonzalez-Rangel, J.A., 2019. Paleomagnetism and tectonics from the late Pliocene to late Pleistocene in the Xalapa monogenetic volcanic field, Veracruz, Mexico, *Bull. geol. Soc. Am.*

Arce, J.L., Layer, P.W., Lassiter, J.C., Benowitz, J.A., Macías, J.L. & Ramírez-Espinosa, J., 2013. 40 Ar/39 Ar dating, geochemistry, and isotopic analyses of the quaternary Sierra de Chichinautzin volcanic field, south of Mexico City: implications for timing, eruption rate, and distribution of volcanism, *Bull. Volcanol.,* **75**(12), 774.

Arce, J.L., Muñoz-Salinas, E., Castillo, M. & Salinas, I., 2015. The∼ 2000 yr BP Jumento volcano, one of the youngest edifices of the Sierra de Chichinautzin Volcanic Field, Central Mexico, *J. Volc. Geotherm. Res.,* **308,** 30–38.

Bloomfield, K., 1975. A late-Quaternary monogenetic volcano field in central Mexico, *Geol. Rundsch.,* **64**(1), 476–497.

Bloomfield, K., 1974. The age and significance of the Tenango Basalt, central Mexico, *Bull. Volcanol.,* **37**(4), 586–595.

Böhnel, H., Morales, J., Caballero, C., Alva, L., McIntosh, G., Gonzalez, S. & Sherwood, G., 1997. Variation of rock magnetic parameters and paleointensities over a single Holocene lava flow, *J. Geomag. Geoelectr.,* **49**(4), 523–542.

Böhnel, H. & Molina-Garza, R., 2002. Secular variation in Mexico during the last 40,000 years, *Phys. Earth planet. Inter.,* **133**(1-4), 99–109.

Böhnel, H., Biggin, A.J., Walton, D., Shaw, J. & Share, J.A., 2003. Microwave palaeointensities from a recent Mexican lava flow, baked sediments and reheated pottery, *Earth planet. Sci. Lett.,* **214**(1), 221–236.

Brown, M.C., Donadini, F., Korte, M., Nilsson, A., Korhonen, K., Lodge, A., Lengyel, S.N. & Constable, C.G., 2015. GEOMAGIA50.v3: 1. General structure and modifications to the archeological and volcanic database, *Earth Planets Space,* **67,** 83.

Constable, C., Korte, M. & Panovska, S., 2016. Persistent high paleosecular variation activity in southern hemisphere for at least 10 000 years, *Earth planet. Sci. Lett.,* **453,** 78–86.

Cox, A., 1969. Confidence limits for the precision parameter κ, *Geophys. J. Int.,* **17**(5), 545–549.

Cromwell, G., Johnson, C.L., Tauxe, L., Constable, C.G. & Jarboe, N.A., 2018. PSV10: a global data set for 0–10 Ma time-averaged field and paleosecular variation studies, *Geochem. Geophys. Geosyst.,* **19**(5), 1533–1558.

Day, R., Fuller, M. & Schmidt, V.A., 1977. Hysteresis properties of titanomagnetites: grain-size and compositional dependence, *Phys. Earth planet. Inter.,* **13**(4), 260–267.

Del Pozzo, A.M., 1982. Monogenetic vulcanism in sierra Chichinautzin, Mexico, *Bull. Volcanol.,* **45**(1), 9.

Demant, A., 1978. Características del Eje Neovolcánico Transmexicano y sus problemas de interpretación, *Revista mexicana de ciencias geológicas,* **2**(2), 172–187.

Doubrovine, P.V., Veikkolainen, T., Pesonen, L.J., Piispa, E., Ots, S., Smirnov, A.V. & Biggin, A.J., 2019. Latitude dependence of geomagnetic paleosecular variation and its relation to the frequency of magnetic reversals: observations from the Cretaceous and Jurassic, *Geochem. Geophys. Geosyst.,* **20,** 1240–1279.

Dunlop, D.J., 2002. Theory and application of the Day plot (Mrs/Ms versus Hcr/Hc) 2. Application to data for rocks, sediments, and soils, *J. geophys. Res.: Solid Earth,* **107**(B3), EPM 5–1-EPM 5-15.

Ferrari, L., Garduño, V.H., Pasquare, G. & Tibaldi, A., 1994. Volcanic and tectonic evolution of central Mexico: Oligocene to present, *Geof. Int.,* **33**(1), 91–105.

Ferrari, L., López-Martínez, M., Aguirre-Díaz, G. & Carrasco-Núñez, G., 1999. Space-time patterns of Cenozoic arc volcanism in central Mexico: From the Sierra Madre Occidental to the Mexican Volcanic Belt, *Geology,* **27**(4), 303–306.

Ferrari, L., Conticelli, S., Vaggelli, G., Petrone, C.M. & Manetti, P., 2000. Late Miocene volcanism and intra-arc tectonics during the early development of the Trans-Mexican Volcanic Belt, *Tectonophysics,* **318**(1-4), 161–185.

Fisher, R.A., 1953. Dispersion on a sphere, *Proc. R. Soc. Lond. A,* **217**(1130), 295–305.

Gómez-Tuena, A., Orozco-Esquivel, M.T. & Ferrari, L., 2007. Igneous petrogenesis of the Trans-Mexican volcanic belt, *Geol. Soc. Am. Spec. Pap.,* **422,** 129–181.

Gonzalez, S., Sherwood, G., Böhnel, H. & Schnepp, E., 1997. Palaeosecular variation in Central Mexico over the last 30000 years: the record from lavas, *Geophys. J. Int.,* **130**(1), 201–219.

Guilbaud, M.N., Arana-Salinas, L., Siebe, C., Barba-Pingarrón, L.A. & Ortiz, A., 2015. Volcanic stratigraphy of a high-altitude mammuthus columbi (Tlacotenco, sierra Chichinautzin), central México, *Bull. Volcanol.,* **77**(3), 17.

Guilbaud, M.N., Siebe, C. & Agustín-Flores, J., 2009. Eruptive style of the young high-Mg basaltic-andesite Pelagatos scoria cone, southeast of México City, *Bull. Volcanol.,* **71**(8), 859.

Herrero-Bervera, E. & Pal, S., 1977. Paleomagnetic study of Sierra de Chichinautzin, Mexico, *Geof. Int.,* **17**(2), 167–180.

Jaimes-Viera, M.C., MartinDel Pozzo, A.L., Layer, P.W., Benowitz, J.A. & Nieto-Torres, A., 2018. Timing the evolution of a monogenetic volcanic field: Sierra Chichinautzin, Central Mexico, *J. Volc. Geotherm. Res.,* **356,** 225–242.

Johnson, C.L., Constable, C.G., Tauxe, L., Barendregt, R., Brown, L.L., Coe, R.S. & Staudigel, H., 2008. Recent investigations of the 0–5 Ma geomagnetic field recorded by lava flows, *Geochem. Geophys. Geosyst.,* **9**(4).

Kirianov, V.Y., Koloskov, A.B., De la Cruz, S. & Martin, A.L., 1990. The major stages of manifestation of recent volcanism in the Chichinautzin zone, *USSR Acad. Sci. Geol. Ser.,* **311,** 432–434.

Kirschvink, J.L., 1980. The least-squares line and plane and the analysis of palaeomagnetic data, *Geophys. J. R. astr. Soc.,* **62**(3), 699–718.

Lanos, P. & Philippe, A., 2017. Hierarchical Bayesian modelling for combining dates in archaeological context, *J. Soc. Fr. Stat.,* **158**(2), 72–88.

Lorenzo-Merino, A., 2016. M.s. Thesis. Historia eruptiva del volcán Pelado (Sierra de Chichinautzin, México). Posgrado en Ciencias de la Tierra. Universidad Nacional Autónoma de México, México D.F. México, 89 pp.

Mahgoub, A.N., Böhnel, H., Siebe, C. & Chevrel, M.O., 2017. Paleomagnetic study of El Metate shield volcano (Michoacán, Mexico) confirms its monogenetic nature and young age (∼ 1250 CE), *J. Volc. Geotherm. Res.,* **336,** 209–218.

Mahgoub, A.N., Juárez-Arriaga, E., Böhnel, H., Siebe, C. & Pavón-Carrasco, F.J., 2019. Late-Quaternary secular variation data from Mexican volcanoes, *Earth planet. Sci. Lett.,* **519,** 28–39.

McFadden, P.L. & McElhinny, M.W., 1990. Classification of the reversal test in palaeomagnetism, *Geophys. J. Int.,* **103**(3), 725–729.

McFadden, P.L., Merrill, R.T., McElhinny, M.W. & Lee, S., 1991. Reversals of the Earth's magnetic field and temporal variations of the dynamo families, *J. geophys. Res.: Solid Earth,* **96**(B3), 3923–3933.

Mejia, V., Böhnel, H., Opdyke, N.D., Ortega-Rivera, M.A., Lee, J.K.W. & Aranda-Gomez, J.J., 2005. Paleosecular variation and time-averaged field recorded in late Pliocene–Holocene lava flows from Mexico, *Geochem. Geophys. Geosyst.,* **6**(7), 2557–2558.

Michalk, D.M., Böhnel, H.N., Nowaczyk, N.R., Aguírre-Diaz, G.J., López-Martínez, M., Ownby, S. & Negendank, J.F., 2013. Evidence for geomagnetic excursions recorded in Brunhes and Matuyama Chron lavas from the trans-Mexican volcanic belt, *J. geophys. Res.: Solid Earth,* **118**(6), 2648–2669.

Mooser, F., Nairn, A.E. & Negendank, J.F., 1974. Palaeomagnetic investigations of the tertiary and quaternary igneous rocks: VIII a palaeomagnetic and petrologic study of volcanics of the valley of Mexico, *Geol. Rundsch.,* **63**(2), 451–483.

Mora Álvarez, G., Caballero Miranda, C., Urrutia Fucugauchi, J. & Uchiumi, S., 1991. Southward migration of volcanic activity in the Sierra de Las Cruces, basin of Mexico-a preliminary K-Ar dating and palaeomagnetic study, *Geof. Int.,* **30**(2), 61–70.

Morales, J., Goguitchaichvili, A. & Urrutia-Fucugauchi, J., 2001. A rock-magnetic and paleointensity study of some Mexican volcanic lava flows during the Latest Pleistocene to the Holocene, *Earth, Planets Space,* **53**(9), 893–902.

Opdyke, N.D., Kent, D.V., Foster, D.A. & Huang, K., 2015. Paleomagnetism of Miocene volcanics on Sao Tome: Paleosecular variation at the Equator and a comparison to its latitudinal dependence over the last 5 Myr, *Geochem. Geophys. Geosyst.,* **16**(11), 3870–3882.

Ortega-Gutiérrez, F., Mitre-Salazar, L.M. & Roldan-Quintana, J., 1992. Carta geológica de la República Mexicana. Consejo de Recursos Minerales y en el Instituto de Geología de la UNAM.

Panovska, S., Constable, C.G. & Brown, M.C., 2018. Global and regional assessments of paleosecular variation activity over the past 100 ka, *Geochem. Geophys. Geosyst.,* **19,** 1559–1580.

Pavón-Carrasco, F.J., Osete, M.L., Torta, J.M. & De Santis, A., 2014. A geomagnetic field model for the Holocene based on archaeomagnetic and lava flow data, *Earth planet. Sci. Lett.,* **388,** 98–109.

Reimer, P.J *et al.*, 2013. IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years cal BP, *Radiocarbon,* **55**(4), 1869–1887.

Ruiz-Martınez, V.C., Osete, M.L., Vegas, R., Nunez-Aguilar, J.I., Urrutia-Fucugauchi, J. & Tarling, D.H., 2000. Palaeomagnetism of Late Miocene to Quaternary volcanics from the eastern segment of the Trans-Mexican Volcanic Belt, *Tectonophysics,* **318**(1-4), 217–233.

Siebe, C., 2000. Age and archaeological implications of Xitle volcano, southwestern Basin of Mexico-City, *J. Volc. Geotherm. Res.,* **104**(1-4), 45–64.

Siebe, C., Rodríguez-Lara, V., Schaaf, P. & Abrams, M., 2004a. Radiocarbon ages of Holocene Pelado, Guespalapa, and Chichinautzin scoria cones, south of Mexico City: implications for archaeology and future hazards, *Bull. Volcanol.,* **66**(3), 203–225.

Siebe, C., Rodrı´, V., Schaaf, P. & Abrams, M., 2004b. Geochemistry, Sr–Nd isotope composition, and tectonic setting of Holocene Pelado, Guespalapa and Chichinautzin scoria cones, south of Mexico City, *J. Volc. Geotherm. Res.,* **130**(3), 197–226.

Siebe, C., Arana-Salinas, L. & Abrams, M., 2005. Geology and radiocarbon ages of Tláloc, Tlacotenco, Cuauhtzin, Hijo del Cuauhtzin, Teuhtli, and Ocusacayo monogenetic volcanoes in the central part of the Sierra Chichinautzin, México, *J. Volc. Geotherm. Res.,* **141**(3-4), 225–243.

Tauxe, L., Constable, C., Johnson, C.L., Koppers, A.A., Miller, W.R. & Staudigel, H., 2003. Paleomagnetism of the southwestern USA recorded by 0–5 Ma igneous rocks, *Geochem. Geophys. Geosyst.,* **4**(4).

Urrutia-Fucugauchi, J., 1996. Palaeomagnetic study of the Xitle-Pedregal de San Angel lava flow, southern Basin of Mexico, *Phys. Earth planet. Inter.,* **97**(1-4), 177–196.

Urrutia-Fucugauchi, J. & Martin del Pozzo, A.L., 1993. Implicaciones de los datos paleomagneticos sobre la edad de la Sierra de Chichinautzin, cuenca de Mexico, *Geof. Int.,* **32**(3), 523–533.

Vlag, P., Alva-Valdivia, L., De Boer, C.B., Gonzalez, S. & Urrutia-Fucugauchi, J., 2000. A rock-and paleomagnetic study of a Holocene lava flow in Central Mexico, *Phys. Earth planet. Inter.,* **118**(3), 259–272.

SUPPORTING INFORMATION

Supplementary data are available at *GJI* online.

Table 1S: Compilation of volcanic data from the TransMexican Volcanic Belt over the last 1.5 Myr

Please note: Oxford University Press is not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than missing material) should be directed to the corresponding author for the paper.

Tab. 1S: Compilation of volcanic data from the TransMexican Volcanic Belt over the last 1.5 Myr

Site	Slat (°N)	Slong (°W)	Volcanic Field	Age (kyrs BP)	Age σ (kyrs)	N	Dec	Inc	kappa	α95	lat (°N	long (°E	Pol	Reference	Rejection
Paricutin-4	19.50	102.25	Michoacan-Guanajuato	0.003	0	7	332	51	239	5.0	62	199	N	Urrutia-Fucugauchi et al. (2004)	
Paricutin-3	19.50	102.25	Michoacan-Guanajuato	0.004	0	6	344	25	47	13.5	73	148	N	Urrutia-Fucugauchi et al. (2004)	Quality criteria
Paricutin M-1	19.48	99.18	Michoacan-Guanajuato	0.005	0.002	6	11	38	238	4.4	80	339	N	Gonzalez et al. (1997)	
Paricutin-6	19.50	102.25	Michoacan-Guanajuato	0.005	0	9	4	42	70	11.1	84	295	N	Urrutia-Fucugauchi et al. (2004)	
Paricutin-9	19.50	102.25	Michoacan-Guanajuato	0.005	0	7	7	34	70	8.0	83	354	N	Urrutia-Fucugauchi et al. (2004)	
Paricutin-10	19.50	102.25	Michoacan-Guanajuato	0.005	0	10	0	45	149	6.3	83	258	N	Urrutia-Fucugauchi et al. (2004)	
Paricutin-11	19.50	102.25	Michoacan-Guanajuato	0.005	0	12	353	34	45	7.3	83	162	N	Urrutia-Fucugauchi et al. (2004)	Quality criteria
Paricutin-12	19.50	102.25	Michoacan-Guanajuato	0.005	0	9	4	18	151	4.5	79	57	N	Urrutia-Fucugauchi et al. (2004)	
19-Paricutin	19.53	102.25	Michoacan-Guanajuato	0.006	0.001	7	47	28	70	7.3	45	346	N	Conte-Fasano et al. (2006)	Disturbed
Paricutin-5	19.50	102.25	Michoacan-Guanajuato	0.006	0	8	13	37	71	11.0	78	340	N	Urrutia-Fucugauchi et al. (2004)	
Paricutin-7	19.50	102.25	Michoacan-Guanajuato	0.006	0	12	7	47	27	11.8	79	293	N	Urrutia-Fucugauchi et al. (2004)	Quality criteria
Paricutin-8	19.50	102.25	Michoacan-Guanajuato	0.006	0	7	32	51	20	15.4	59	318	N	Urrutia-Fucugauchi et al. (2004)	Quality criteria
Paricutin-1	19.50	102.25	Michoacan-Guanajuato	0.007	0	6	0	18	107	8.9	80	78	N	Urrutia-Fucugauchi et al. (2004)	
Paricutin-2	19.50	102.25	Michoacan-Guanajuato	0.007	0	6	8	40	241	5.9	82	323	N	Urrutia-Fucugauchi et al. (2004)	
Ceboruco CB7/14/25/26	21.12	104.52	Ceboruco San-Pedro	0.08	0	25	8	42	90	3.1	82	321	N	Böhnel et al. (2016)	
El Jorullo	19.48	102.25	Michoacan-Guanajuato	0.184	0.007	20	8	51	634	2.6	76	287	N	Gratton et al. (2005)	
24-El Jorullo	19.00	101.75	Michoacan-Guanajuato	0.19	0.01	7	9	56	212	3.8	71	281	N	Conte-Fasano et al. (2006)	
San Martin flanco Norte (lavas)-C	18.5811	95.1917		0.23		9	9.9	42	100.1	5.2	79	321	N	Mahgoub et al. (2019)	
El Jorullo	18.97	101.70	Michoacan-Guanajuato	0.26		31	3	38	214	1.8	87	307	N	Alva-Valdivia et al. (2019)	
SM Pottery (Colima volcano)	19.46	103.51	Colima	0.28	0.065	5	4	27	677	2.6	84	39	N	Cifuentes-Nava et al. (2017)	Disturbed
Ceboruco	21.14	104.50	Ceboruco San-Pedro	0.4	0.01	7	0	37	361	3.2	90	76	N	Böhnel & Molina-Garza (2002)	
Ceboruco CB8/9/11/16	21.09	104.58	Ceboruco San-Pedro	0.69	0.27	50	347	36	74	2.4	78	162	N	Böhnel et al. (2016)	
El Metate MT2	19.49	102.03	Michoacan-Guanajuato	0.71	0.06	15	348	35	71	4.6	79	169	N	Mahgoub et al. (2017a)	
El Metate MT4	19.58	101.97	Michoacan-Guanajuato	0.71	0.06	10	349	39	201	3.4	79	183	N	Mahgoub et al. (2017a)	
El Metate MT6.1	19.47	101.96	Michoacan-Guanajuato	0.71	0.06	9	348	34	186	3.8	79	166	N	Mahgoub et al. (2017a)	
El Metate MT1	19.47	101.96	Michoacan-Guanajuato	0.71	0.06	16	353	36	143	3.1	83	174	N	Mahgoub et al. (2017a)	
Toxtlacuaya	19.40	96.90	Eastern TMVB	0.8	0.1	5	345	34	248	1.8	76	173	N	Böhnel & Molina-Garza (2002)	
DL	19.62	96.99	Eastern TMVB	0.91	0.05	31	342	33	565	1.1	73	171	N	Michalk et al. (2010)	
Toaxtlacoaya (lavas - blocks)-C	19.4	96.9		0.95	0.06	50	343	34	1050	1.7	74	174	N	Mahgoub et al. (2019)	
Xitle XT-9	19.11	99.27	Chichinautzin	1.6	0.09	7	350	32	395	3.0	80	162	N	Urrutia-Fucugauchi (1996)	
Xitle XT-7	19.10	99.27	Chichinautzin	1.6	0.09	6	1	33	265	4.1	89	40	N	Urrutia-Fucugauchi (1996)	
Xitle XT-6	19.25	99.26	Chichinautzin	1.6	0.09	9	355	37	123	4.7	85	188	N	Urrutia-Fucugauchi (1996)	
Xitle 6	19.30	99.20	Chichinautzin	1.6	0.09	17	358	34	301	2.1	88	152	N	Herrero & Pal (1978)	
Xitle 7	19.30	99.20	Chichinautzin	1.6	0.09	11	355	34	86	5.0	85	164	N	Herrero & Pal (1978)	
Xitle 11	19.30	99.20	Chichinautzin	1.6	0.09	12	16	36	230	2.9	75	346	N	Herrero & Pal (1978)	
Xitle 13	19.30	99.20	Chichinautzin	1.6	0.09	8	355	39	114	5.2	85	202	N	Herrero & Pal (1978)	
Xitle 14	19.30	99.20	Chichinautzin	1.6	0.09	8	357	52	151	4.5	76	250	N	Herrero & Pal (1978)	
Xitle 15	19.30	99.20	Chichinautzin	1.6	0.09	7	356	34	62	7.7	86	162	N	Herrero & Pal (1978)	
Xitle JM	19.32	99.19	Chichinautzin	1.6	0.09	13	352	36	269	2.5	82	177	N	Morales et al. (2001)	
Xitle Flow 1	19.32	99.17	Chichinautzin	1.6	0.09	9	4	32	87	5.6	86	18	N	Alva-Valdivia (2005)	
Xitle Flow 2	19.32	99.17	Chichinautzin	1.6	0.09	8	0	35	351	3.0	90	81	N	Alva-Valdivia (2005)	
Xitle Flow 3	19.32	99.17	Chichinautzin	1.6	0.09	10	2	34	131	4.2	88	10	N	Alva-Valdivia (2005)	
Xitle Flow 4	19.32	99.17	Chichinautzin	1.6	0.09	10	3	32	156	3.9	87	25	N	Alva-Valdivia (2005)	
Xitle Flow 8	19.32	99.17	Chichinautzin	1.6	0.09	8	359	33	57	7.4	88	116	N	Alva-Valdivia (2005)	Quality criteria
Xitle Flow 5	19.32	99.17	Chichinautzin	1.6	0.09	8	3	35	72	6.6	87	351	N	Alva-Valdivia (2005)	
Xitle Flow 6	19.32	99.17	Chichinautzin	1.6	0.09	9	356	30	309	2.9	85	131	N	Alva-Valdivia (2005)	
Xitle Flow 7	19.32	99.17	Chichinautzin	1.6	0.09	9	5	36	280	3.1	85	342	N	Alva-Valdivia (2005)	
Xitle Flow 9	19.32	99.17	Chichinautzin	1.6	0.09	7	357	38	117	5.6	87	207	N	Alva-Valdivia (2005)	
Xitle Flow 10	19.32	99.17	Chichinautzin	1.6	0.09	5	3	38	393	3.9	87	315	N	Alva-Valdivia (2005)	
Xitle P-8	19.33	99.15	Chichinautzin	1.6	0.09	8	356	30	67	6.8	85	131	N	Urrutia-Fucugauchi (1996)	
Xitle CU-2	19.36	99.15	Chichinautzin	1.6	0.09	6	354	36	151	4.5	84	178	N	Urrutia-Fucugauchi (1996)	
Xitle CU-5	19.32	99.15	Chichinautzin	1.6	0.09	5	348	15	293	4.5	74	127	N	Urrutia-Fucugauchi (1996)	
Xitle CU-3	19.32	99.15	Chichinautzin	1.6	0.09	5	5	41	217	4.6	84	308	N	Urrutia-Fucugauchi (1996)	
Xitle IN-4	19.31	99.12	Chichinautzin	1.6	0.09	4	358	28	41	8.7	85	105	N	Urrutia-Fucugauchi (1996)	Quality criteria
Xitle CU-8	19.30	99.14	Chichinautzin	1.6	0.09	15	357	37	61	5.1	87	197	N	Urrutia-Fucugauchi (1996)	
Xitle CC-1	19.29	99.13	Chichinautzin	1.6	0.09	7	4	32	119	5.5	86	17	N	Urrutia-Fucugauchi (1996)	
Xitle CU-1	19.35	99.13	Chichinautzin	1.6	0.09	6	357	35	477	3.1	87	170	N	Urrutia-Fucugauchi (1996)	
Xitle XT-4	19.28	99.12	Chichinautzin	1.6	0.09	6	0	35	295	3.9	90	261	N	Urrutia-Fucugauchi (1996)	
Xitle	19.19	99.11	Chichinautzin	1.6	0.09	15	347	36	521	1.7	78	177	N	Böhnel et al. (1997)	
Xitle XP-6	19.13	99.11	Chichinautzin	1.6	0.09	5	11	33	66	9.5	80	355	N	Urrutia-Fucugauchi (1996)	
Xitle, S-9	19.32	99.18	Chichinautzin	1.6	0.09	9	350	35	663	2.0	81	172	N	Gonzalez et al. (1997)	
Xitle XT-1	19.18	99.10	Chichinautzin	1.6	0.09	6	357	32	276	4.0	87	139	N	Urrutia-Fucugauchi & Martin del Pozzo (1993)	
CH-IV	19.11	99.16	Chichinautzin	1.75	0.13	8	349	32	181	5.7	79	163	N	This Study	
CH-I	19.11	99.16	Chichinautzin	1.75	0.13	7	357	40	153	6.2	85	224	N	This Study	
PL-CH1	19.12	99.15	Chichinautzin	1.75	0.13	8	354	34	953	3	84	167	N	This Study	
CH-2	19.12	99.13	Chichinautzin	1.75	0.13	8	3	30	214	6.3	86	37	N	This Study	
Chichinautzin 1	19.10	99.10	Chichinautzin	1.75	0.13	8	358	27	73	6.5	85	103	N	Herrero & Pal (1978)	
CH-1	19.09	99.08	Chichinautzin	1.75	0.13	7	357	30	91	9.7	86	125	N	This Study	
Chichinautzin (lavas - blocks)-B	19.02	99.14	Chichinautzin	1.75	0.13	23	3.4	34	98.4	3.1	87	1	N	Mahgoub et al. (2019)	
Punti-Agudo (lavas - blocks)-C	18.447	95.0995		1.8	22	12	355	36	79.3	4.9	85	192	N	Mahgoub et al. (2019)	
Cicapien (lavas - blocks)-A	19.5786	102.0919		1.8	0.06	25	360	19	27.42	5.6	80	80	N	Mahgoub et al. (2019)	Quality criteria
SJC	19.47	103.74	Colima	1.9	0.9	7	351	40	633	2.2	81	189	N	Cifuentes-Nava et al. (2017)	
Jumento	19.20	99.31	Chichinautzin	1.97	0.1	16	349	50	233	4.4	75	222	N	This Study	
El Jumento (lavas - massively distributed)-B	19.1867	99.3201	Chichinautzin	1.97	0.1	25	354	32	51.69	4.1	84	156	N	Mahgoub et al. (2019)	Quality criteria
AX	19.47	102.08	Michoacan-Guanajuato	2	10	13	335	37	23	8.8	67	175	N	Michalk et al. (2013)	Quality criteria
CB17	21.21	104.56	Ceboruco San-Pedro	2	31	6	358	45	68	7.4	84	237	N	Pétronille et al. (2005)	
Guadalupe SC1	19.32	99.02	Chichinautzin	2	0.56	8	9	37	85	6.0	81	341	N	This Study	
Tetimpa	19.05	98.45	Eastern TMVB	2.3	0.1	8	353	39	201	3.9	83	197	N	Böhnel & Molina-Garza (2002)	
Nealtican (lavas - quarries)-B	18.9893	98.482		2.3	0.08	36	360	32	90.43	2.5	89	101	N	Mahgoub et al. (2019)	
Pelagatos A2	19.10	98.93	Chichinautzin	2.6	0.2	8	3	20	618	3.7	80	63	N	This Study	
Pelagatos MMA-23-A	19.12	98.91	Chichinautzin	2.6	0.2	8	1	27	1459	2.4	85	70	N	This Study	
El Parajo 1	19.64	97.45	Eastern TMVB	2.974	0.094	18	27	22	30	6.6	63	6	N	Juarez-Arriaga et al. (2018)	Quality criteria
El Parajo 3	19.57	97.44	Eastern TMVB	2.974	0.094	7	24	10	180	4.5	63	21	N	Juarez-Arriaga et al. (2018)	Disturbed
El Parajo 2	19.60	97.49	Eastern TMVB	2.974	0.094	10	14	11	95	5.0	70	37	N	Juarez-Arriaga et al. (2018)	
Jalapa	19.65	96.96	Eastern TMVB	3.2	0.2	8	8	28	218	3.8	81	24	N	Böhnel & Molina-Garza (2002)	
Coacoatzintla (lavas - blocks)-C	19.65	96.96		3.2	0.04	16	3.6	25	174.9	2.8	83	54	N	Mahgoub et al. (2019)	
Cerro el Frijol	19.46	101.55	Michoacan-Guanajuato	3.23		8	346	23	87	9.6	75	142	N	Garcia-Quintana et al. (2016)	
Malpais de Zacapu, El Infiernillo	19.86	101.85	Michoacan-Guanajuato	3.4	0.05	21	357	52	103	3.2	77	247	N	Mahgoub et al. (2017b)	
El Jabali M-5	19.45	101.98	Michoacan-Guanajuato	4.2	0.4	3	20	45	42	19.4	70	323	N	Gonzalez et al. (1997)	Quality criteria
El Jabali	19.45	102.11	Michoacan-Guanajuato	4.2	0.4	6	13	34	597	2.7	78	350	N	Böhnel & Molina-Garza (2002)	
21-El Jabalí	19.42	102.13	Michoacan-Guanajuato	4.2	0.4	6	350	26	898	2.2	79	139	N	Conte-Fasano et al. (2006)	
Urutzen (lavas - massively distributed)-A	19.5702	101.9412		4.2	0.22	13	12.7	36	231.7	3	78	345	N	Mahgoub et al. (2019)	
Texcal	19.58	97.54	Eastern TMVB	4.27	0.37	22	356	27	221	2.2	84	119	N	Juarez-Arriaga et al. (2018)	
AG2	19.18	100.25	Valle del Bravo	5	2	5	2	18	302	4.4	80	69	N	Michalk et al. (2013)	
El Metate M-6	19.57	102.11	Michoacan-Guanajuato	5.3	0.45	5	82	42	301	4.4	15	327	N	Gonzalez et al. (1997)	Disturbed
18-El Metate	19.57	102.02	Michoacan-Guanajuato	5.3	0.45	8	16	25	816	1.9	73	8	N	Conte-Fasano et al. (2006)	
Cerro Cendanas	19.53	101.73	Michoacan-Guanajuato	6.79		8	334	42	33	7.6	66	184	N	Garcia-Quintana et al. (2016)	Quality criteria
Tabaquillo	19.12	99.29	Chichinautzin	7	9	8	360	44	1141	2.7	83	261	N	This Study	
Tlaloc A5	19.14	99.01	Chichinautzin	7.1	0.2	7	2	10	180	6.9	76	73	N	This Study	
Tendeparacua (lavas - road cut)-A	19.8853	101.4502		7.1	0.14	9	340	38	668.7	2	71	177	N	Mahgoub et al. (2019)	
Cerro La Taza	19.53	101.72	Michoacan-Guanajuato	9.4	0.8	8	328	14	181	4.8	57	151	N	Garcia-Quintana et al. (2016)	Disturbed
15-La Taza	19.53	101.69	Michoacan-Guanajuato	9.4	0.8	10	337	30	134	4.2	68	163	N	Conte-Fasano et al. (2006)	
Tres Cruces, S-6	19.12	99.49	Chichinautzin	9.4	0.3	6	337	56	463	3.1	63	216	N	Gonzalez et al. (1997)	
Tres Cruces Sites 1+2	19.10	99.50	Chichinautzin	9.4	0.3	16	339	50	196	3.7	68	206	N	Vlag et al. (2000)	
Tenango TEO-ALTO	19.11	99.60	Chichinautzin	9.5	1	8	358	65	163	7.2	62	258	N	This Study	
Tenango TEO-BAJO	19.11	99.60	Chichinautzin	9.5	1	7	3	71	315	5.2	54	263	N	This Study	
Tenango1 (lavas - blocks)-B	19.0895	99.6258	Chichinautzin	9.5	1	10	18	36	98.5	4.9	73	344	N	Mahgoub et al. (2019)	
DR	19.12	97.54	Eastern TMVB	10	10	9	10	28	234	3.4	80	15	N	Michalk et al. (2013)	
Cima 12	19.10	99.20	Chichinautzin	10.1	0.6	13	6	16	21	9.2	78	52	N	Herrero & Pal (1978)	Quality criteria
Cima 2	19.10	99.19	Chichinautzin	10.1	0.6	7	17	22	71	7.2	72	14	N	Urrutia-Fucugauchi & Martin del Pozzo (1993)	
Cima 3	19.10	99.17	Chichinautzin	10.1	0.6	7	355	41	139	5.1	84	215	N	Gonzalez et al. (1997)	
Tlacotenco MMA-25-A	19.15	98.98	Chichinautzin	10.2	3.8	8	12	12	253	5.8	73	38	N	This Study	
Tlacotenco MMA-C	19.16	98.99	Chichinautzin	10.2	3.8	7	3	4	238	5.0	73	71	N	This Study	
El Huanillo M-2	19.67	102.22	Michoacan-Guanajuato	10.4	0.7	3	42	11	540	5.3	47	1	N	Gonzalez et al. (1997)	Disturbed
La Taza (lavas - massively distributed)-A	19.5303	101.7328	Michoacan-Guanajuato	10.5	0.22	7	349	15	73.7	7.1	74	122	N	Mahgoub et al. (2019)	
Juanyan (bombs)-A	19.6857	101.9803		10.5	0.8	11	359	44	115.5	4.3	84	248	N	Mahgoub et al. (2019)	
Pelado, S-10	19.14	101.42	Chichinautzin	10.8	0.6	7	352	12	60	7.9	75	110	N	Gonzalez et al. (1997)	Quality criteria
El Pelado 8	19.20	99.20	Chichinautzin	10.8	0.6	9	7	33	51	7.3	83	0	N	Herrero & Pal (1978)	Quality criteria
El Pelado JB	19.19	99.17	Chichinautzin	10.8	0.6	8	10	17	198	3.9	76	37	N	Morales et al. (2001)	Age
Pelado P-2	19.15	99.21	Chichinautzin	10.8	0.6	6	355	15	130	5.9	78	104	N	Urrutia-Fucugauchi & Martin del Pozzo (1993)	

Pelado SITIO C	19.12	99.28	Chichinautzin	10.8	0.6	6	359	38	68	10.5	88	238	N	This Study	
Pelado SITIO D	19.14	99.17	Chichinautzin	10.8	0.6	8	14	22	112	6.4	75	19	N	This Study	
Pelado SITIO B	19.12	99.27	Chichinautzin	10.8	0.6	8	347	29	124	6.0	77	156	N	This Study	
Pelado SITIO A	19.12	99.27	Chichinautzin	10.8	0.6	6	358	38	79	8.7	87	221	N	This Study	
Pelado PL-02	19.12	99.26	Chichinautzin	10.8	0.6	8	354	34	953	4.0	84	167	N	This Study	
Pelado PL-01	19.14	99.26	Chichinautzin	10.8	0.6	8	12	22	121	5.4	76	23	N	This Study	
El Pelado 9	19.20	99.20	Chichinautzin	10.8	0.6	8	5	27	115	5.2	83	36	N	Herrero & Pal (1978)	
El Pelado 10	19.20	99.20	Chichinautzin	10.8	0.6	9	6	35	118	4.8	84	349	N	Herrero & Pal (1978)	
Pelado (lavas - blocks)-B	19.12	99.19	Chichinautzin	10.8	0.6	12	18	18	115.1	4.1	70	18	N	Mahgoub et al. (2019)	
Cerro del Agua A4	19.01	98.98	Chichinautzin	12.6	0.7	8	5	17	187	5.6	79	55	N	This Study	
El Melón (lavas – blocks & bombs)-A	19.6706	101.4287		14	0.6	12	349	49	261.5	2.7	76	215	N	Mahgoub et al. (2019)	
upper Toluca pumice (lavas)-B	19.2233	99.7875		14.4	0.1	6	348	54	156.2	5.4	72	227	N	Mahgoub et al. (2019)	
Cerro Hueco (lavas - massively distributed)-A	19.7019	101.4585		14.8	0.47	16	353	49	42.43	5.7	78	227	N	Mahgoub et al. (2019)	Quality criteria
Dos Cerros 1 MMA-46	19.17	98.87	Chichinautzin	16.6	0.4	8	2	50	154	6.2	78	270	N	This Study	
Dos Cerros 2 MMA-44	19.16	98.87	Chichinautzin	16.6	0.6	8	10	45	174	5.1	78	311	N	This Study	
Dos Cerros (lavas - road cut)-B	19.1557	98.8684	Chichinautzin	16.6	0.4	15	345	48	208.6	2.7	73	211	N	Mahgoub et al. (2019)	
DV	19.12	97.54	Eastern TMVB	16.8	0.75	8	12	26	231	3.4	77	16	N	Michalk et al. (2013)	
Tecuitlapa mar (bombs)-C	19.121	97.544		16.8	0.75	24	8.8	28	132.8	2.6	81	18	N	Mahgoub et al. (2019)	
Molcajete Zipiajo (lavas)-A	19.8127	102.0288		17.9	0.8	13	19.9	33	72.07	4	71	350	N	Mahgoub et al. (2019)	
Molcajete de Eréndira (lava - blocks)-A	19.8381	101.8746		18.7	0.97	13	336	59	118.7	3.8	62	217	N	Mahgoub et al. (2019)	
Raices-Cajete (lavas - blocks)-B	19.1058	99.2406	Chichinautzin	18.9	0.34	6	359	47	193.8	4.8	81	255	N	Mahgoub et al. (2019)	
22-Cerro Urujuato	19.00	102.20	Michoacan-Guanajuato	20	20	13	338	17	403	2.1	66	145	N	Conte-Fasano et al. (2006)	Age
16-Cerro Cainjuata	19.66	102.03	Michoacan-Guanajuato	20	20	11	7	41	346	2.5	82	316	N	Conte-Fasano et al. (2006)	Age
La Mina M-10	19.71	101.92	Michoacan-Guanajuato	20.8	1.1	6	340	58	213	4.6	64	220	N	Gonzalez et al. (1997)	
11-La Mina	19.70	101.40	Michoacan-Guanajuato	20.8	1.1	8	346	5	633	2.2	68	119	N	Conte-Fasano et al. (2006)	
Tres Cumbres TC-5	19.10	99.26	Chichinautzin	21.5	1.8	6	3	22	317	3.8	82	60	N	Urrutia-Fucugauchi & Martin del Pozzo (1993)	
Nevado de Colima	19.25	103.53	Colima	22.4	0.1	23	1	34	12	9.0	89	19	N	Clement et al. (1993)	Quality criteria
Ajusco JL	19.19	99.25	Chichinautzin	22.6	0.3	10	359	45	131	4.2	83	254	N	Morales et al. (2001)	
Malinale 1	19.21	99.21	Chichinautzin	22.8	1.4	6	6	33	513	3.0	84	2	N	Urrutia-Fucugauchi & Martin del Pozzo (1993)	
Malinale 2	19.22	99.21	Chichinautzin	22.8	1.4	5	359	34	175	5.8	89	139	N	Gonzalez et al. (1997)	
AY	19.48	102.02	Michoacan-Guanajuato	23	31	10	5	33	43	7.4	85	5	N	Michalk et al. (2013)	Quality criteria
Mazatepec SSC2	19.32	99.04	Chichinautzin	23	4	8	357	34	149	6.3	87	158	N	This Study	
Cuautl, S-7	19.17	99.42	Chichinautzin	23.5	0.5	6	343	17	255	4.2	71	141	N	Gonzalez et al. (1997)	
14-El Estribo	19.52	101.66	Michoacan-Guanajuato	25	4	5	304	30	170	5.9	37	174	T	Conte-Fasano et al. (2006)	Disturbed
BC	19.40	102.11	Michoacan-Guanajuato	26	58	16	18	34	20	8.4	73	348	N	Michalk et al. (2013)	Quality criteria
EE El Tajo	20.72	103.58	Sierra de la Primavera	26.2	0.7	3	5	54	68	15.1	76	273	N	Urrutia-Fucugauchi et al. (1988)	
Tezontle, S-5	19.22	99.47	Chichinautzin	26.3	0.8	7	353	64	318	3.4	63	250	N	Gonzalez et al. (1997)	
El Pueblito (lavas - road cut)-A	19.8204	101.9247		26.4	0.125	8	8.9	35	531.8	2.4	82	350	N	Mahgoub et al. (2019)	
CB14	21.16	104.75	Ceboruco San-Pedro	27	7	12	355	40	253	2.7	85	185	N	Pétronille et al. (2005)	
Tochimilco (lavas - massively distributed)-B	18.874	98.6036		27.7	0.97	10	335	-11	111.8	4.6	55	130	N	Mahgoub et al. (2019)	Transitional
Col6	19.56	103.61	Colima	28	8	10	11	36	26	9.7	80	342	N	Garcia-Ruiz et al. (2016)	Quality criteria
Las Cabras (lavas - road cut) & (bombs)-A	19.8301	101.8983		28.1	0.41	6	335	-29	63.22	8.5	47	115	N	Mahgoub et al. (2019)	Transitional
Alberca de los Espinos (bombs)-A	19.9037	101.7729		29.3	0.22	18	348	54	100.3	3.5	72	224	N	Mahgoub et al. (2019)	
Col8	19.57	103.62	Colima	30	12	4	314	9	96	7.2	43	154	T	Garcia-Ruiz et al. (2016)	Transitional
Jorullo JO-12	19.00	101.70	Michoacan-Guanajuato	30	30	4	355	32	589	3.4	85	150	N	Maciel Peña et al. (2014)	
FF El Colli	20.72	103.58	Sierra de la Primavera	31	0.9	3	337	29	115	11.5	68	157	N	Urrutia-Fucugauchi et al. (1988)	
EA	18.93	97.43	Eastern TMVB	31.7	1.1	9	355	36	60	6.7	85	186	N	Michalk et al. (2013)	
S Cd Serdan (lavas - road cut)-C	18.9328	97.4357		31.7	1.1	27	352	39	46.6	4.1	82	195	N	Mahgoub et al. (2019)	Quality criteria
La Primavera	20.66	103.46	La Primavera	31.9	4.1	7	5	25	123	7.7	81	43	N	Böhnel & Molina-Garza (2002)	
Rancho Seco (lavas - road cut) & bombs)-A	19.6161	101.4707		32	0.92	11	334	60	60.27	5.9	60	217	N	Mahgoub et al. (2019)	
El Caracol (lavas - road cut)-A	19.9624	101.6918		32.4	1.2	9	344	52	121.2	4.7	71	212	N	Mahgoub et al. (2019)	
8-El Pueblito	19.82	101.92	Michoacan-Guanajuato	33	7	8	22	34	306	3.2	69	348	N	Conte-Fasano et al. (2006)	
El Pueblito M-7	19.82	102.01	Michoacan-Guanajuato	33.4	6.6	5	4	40	227	5.1	85	309	N	Gonzalez et al. (1997)	
Col7	19.56	103.61	Colima	34	7	10	11	41	40	7.8	79	323	N	Garcia-Ruiz et al. (2016)	Quality criteria
Teuhtli A1	19.23	99.05	Chichinautzin	36	1.8	8	353	31	119	8.5	83	151	N	This Study	
Teuhtli 5	19.20	99.02	Chichinautzin	36	1.8	11	345	19	118	4.2	73	140	N	Herrero & Pal (1978)	
Teuhtli (lavas - road cut)-B	19.2438	99.0539	Chichinautzin	36	1.8	8	356	27	1066	1.7	83	120	N	Mahgoub et al. (2019)	
La Joya	19.59	96.99	Eastern TMVB	41.7	2.4	3	357	23	450	5.8	82	104	N	Böhnel & Molina-Garza (2002)	
Col13	19.47	103.52	Colima	44	15	8	344	44	656	2.8	74	193	N	Garcia-Ruiz et al. (2016)	
Col14	19.47	103.52	Colima	44	15	9	351	39	166	3.6	81	185	N	Garcia-Ruiz et al. (2016)	
La Joya flow (lavas - blocks)-C	19.59	96.99		45.4	2.3	10	354	25	337.1	2.6	82	124	N	Mahgoub et al. (2019)	
DX	18.94	97.47	Eastern TMVB	46	0.07	15	2	31	55	5.2	87	42	N	Michalk et al. (2013)	Quality criteria
Serdan (lavas - road cut)-C	18.9347	97.4719		46	0.7	24	359	31	62.2	3.8	88	100	N	Mahgoub et al. (2019)	
BB	19.43	102.09	Michoacan-Guanajuato	47	45	12	2	32	24	9.1	87	35	N	Michalk et al. (2013)	Quality criteria
Col2	19.53	103.52	Colima	49	22	6	29	21	36	9.6	61	359	N	Garcia-Ruiz et al. (2016)	Quality criteria
Col3	19.53	103.51	Colima	49	22	7	26	15	39	8.5	62	8	N	Garcia-Ruiz et al. (2016)	Quality criteria
Tacambaro Tac-17	19.23	101.57	Michoacan-Guanajuato	50	40	8	346	35	52	8.2	77	171	N	Maciel Peña et al. (2014)	Quality criteria
CB16	21.21	104.59	Ceboruco San-Pedro	57	5	8	358	30	149	5.1	85	96	N	Pétronille et al. (2005)	
Tacambaro Tac-02	19.04	101.59	Michoacan-Guanajuato	60	20	7	2	39	58	8.4	87	290	N	Maciel Peña et al. (2014)	Quality criteria
Tacambaro Tac-22	19.21	101.46	Michoacan-Guanajuato	60	50	4	5	11	37	10.8	76	58	N	Maciel Peña et al. (2014)	Quality criteria
17-Cerro Paracho	19.62	102.07	Michoacan-Guanajuato	60	10	8	16	23	211	3.8	73	12	N	Conte-Fasano et al. (2006)	
Tacambaro Tac-23	19.21	101.46	Michoacan-Guanajuato	60	50	8	353	46	94	6.3	80	222	N	Maciel Peña et al. (2014)	
Col5	19.54	103.52	Colima	61	8	8	353	27	75	5.8	82	130	N	Garcia-Ruiz et al. (2016)	
Col18	19.62	103.49	Colima	62	14	10	347	51	77	5.4	73	215	N	Garcia-Ruiz et al. (2016)	
Col19	19.62	103.49	Colima	62	14	9	346	53	224	3.4	71	218	N	Garcia-Ruiz et al. (2016)	
EG	21.20	104.55	Ceboruco San-Pedro	63	7	16	331	51	52	5.3	62	194	N	Michalk et al. (2013)	Quality criteria
Col11	19.47	103.82	Colima	69	5	7	3	33	36	10.0	87	13	N	Garcia-Ruiz et al. (2016)	Quality criteria
Tancitaro TAN_08	19.40	102.22	Michoacan-Guanajuato	70		6	350	25	117	5.28	79	136	N	Garcia-Ruiz et al. (2017b)	
K La Cuesta	20.72	103.58	Sierra de la Primavera	71.3		16	8	53	12	11.1	75	284	N	Urrutia-Fucugauchi et al. (1988)	Quality criteria
MAS_01	20.54	104.72	Mascota	73	14	6	355	55	76	8.7	74	240	N	Garcia-Ruiz et al. (2017a)	
Maar Alberca S-02	20.39	101.20	Michoacan-Guanajuato	73	24	8	20	33	62	6.6	71	353	N	Uribe-Cifuentes & Urrutia-Fucugauchi (1999)	
Pueblo Viejo AT-3	18.53	99.20	Chichinautzin	80	20	8	357	57	636	3.6	71	254	N	This Study	
Iztaccihuatl, 1967-82	19.20	98.70	Popocatepetl area	80	20	8	356	40	178	4.2	85	216	N	Steele (1985)	
Iztaccihuatl, 1967-29	19.20	98.70	Popocatepetl area	80	20	7	7	38	73	7.1	83	332	N	Steele (1985)	
Iztaccihuatl, 1968-30	19.20	98.70	Popocatepetl area	80	20	7	357	32	79	6.8	87	139	N	Steele (1985)	
Iztaccihuatl, 1968-31	19.20	98.70	Popocatepetl area	80	20	7	4	36	64	7.6	86	339	N	Steele (1985)	
Col17	19.48	103.49	Colima	81	8	9	352	41	46	7.7	82	196	N	Garcia-Ruiz et al. (2016)	Quality criteria
DF	19.11	99.93	Valle del Bravo	81	35	9	12	32	68	6.3	79	357	N	Michalk et al. (2013)	
Tancitaro Tan10	19.16	102.22	Michoacan-Guanajuato	82	24	7	33	1	69	7.3	53	14	N	Maciel Peña et al. (2009)	Transitional
Col12	19.49	103.52	Colima	83	5	9	10	41	67	6.4	80	321	N	Garcia-Ruiz et al. (2016)	
R Las Canoas	20.72	103.58	Sierra de la Primavera	83.6		16	6	29	23	7.8	82	28	N	Urrutia-Fucugauchi et al. (1988)	Quality criteria
EJ	21.03	104.39	Ceboruco San-Pedro	85	19	14	350	49	84	4.4	77	212	N	Michalk et al. (2013)	
CB01	21.03	104.39	Ceboruco San-Pedro	85	19	9	350	56	130	4.9	72	229	N	Pétronille et al. (2005)	
Col1	19.53	103.54	Colima	91	7	9	359	42	40	7.4	85	246	N	Garcia-Ruiz et al. (2016)	Quality criteria
I Toba Tala	20.72	103.58	Sierra de la Primavera	96	8	20	180	35	4	18.3	-50	256	N	Urrutia-Fucugauchi et al. (1988)	Quality criteria
Col4	19.48	103.55	Colima	97	13	5	349	35	48	9.0	80	167	N	Garcia-Ruiz et al. (2016)	Quality criteria
Col9	19.59	103.59	Colima	104	9	8	354	43	66	7.4	82	212	N	Garcia-Ruiz et al. (2016)	
AV	21.22	104.59	Ceboruco San-Pedro	108	22	10	12	25	36	8.2	76	19	N	Michalk et al. (2013)	Quality criteria
AL2	19.17	100.24	Valle del Bravo	109	45	9	7	33	109	4.9	83	359	N	Michalk et al. (2013)	
Tancitaro TAN_02	19.16	102.48	Michoacan-Guanajuato	110	33	7	8	46	109	5.06	79	298	N	Garcia-Ruiz et al. (2017b)	
CB15	21.19	104.58	Ceboruco San-Pedro	111	22	7	12	42	96	8.6	79	328	N	Pétronille et al. (2005)	
F El Burro	20.72	103.58	Sierra de la Primavera	112	15	6	0	40	6	30.7	88	256	N	Urrutia-Fucugauchi et al. (1988)	Quality criteria
TL1	20.82	103.80	Tequila	115	18	6	359	23	78	7.7	81	83	N	Rodriguez Ceja et al. (2006)	
CB07	21.19	104.72	Ceboruco San-Pedro	117	10	6	320	23	26	14.3	51	158	N	Pétronille et al. (2005)	Quality criteria
MAS_14	20.51	104.76	Mascota	163	13	4	339	32	47	10.24	70	160	N	Garcia-Ruiz et al. (2017a)	Quality criteria
MAS-5	20.51	104.76	Mascota	163	13	9	341	20	123	4.7	69	139	N	Maillol et al. (1997)	
Tancitaro Tan11	19.01	102.07	Michoacan-Guanajuato	163	37	7	349	44	198	4.3	78	204	N	Maciel Peña et al. (2009)	
MAS-7	20.58	104.88	Mascota	166	22	5	3	35	181	5.7	87	9	N	Maillol et al. (1997)	
7-El Picacho	19.82	101.95	Michoacan-Guanajuato	170	30	9	350	17	140	4.4	75	121	N	Conte-Fasano et al. (2006)	
Col20	19.62	103.76	Colima	172	21	10	354	39	184	3.6	84	191	N	Garcia-Ruiz et al. (2016)	
TL5	20.87	103.84	Tequila	178	8	3	0	23	56	8.8	81	76	N	Rodriguez Ceja et al. (2006)	Quality criteria
CP	20.87	103.84	Tequila	178	8	7	334	23	72	7.2	64	151	N	Michalk et al. (2013)	
Col16	19.49	103.50	Colima	184	10	9	14	38	39	8.2	77	336	N	Garcia-Ruiz et al. (2016)	Quality criteria
CT	20.81	103.85	Tequila	191	13	7	359	29	49	8.8	85	86	N	Michalk et al. (2013)	Quality criteria
TM3	20.81	103.85	Tequila	191	13	6	11	26	128	6.5	77	19	N	Rodriguez Ceja et al. (2006)	
CV	20.79	103.85	Tequila	196	8	8	359	25	42	8.6	82	83	N	Michalk et al. (2013)	Quality criteria
MAS-6	20.50	104.76	Mascota	196	11	8	357	38	422	2.7	87	182	N	Maillol et al. (1997)	
TM2	20.79	103.85	Tequila	196	8	5	346	42	61	8.9	77	184	N	Rodriguez Ceja et al. (2006)	
Tancitaro Tan1	19.42	102.30	Michoacan-Guanajuato	209	41	3	24	8	56	16.5	62	18	N	Maciel Peña et al. (2009)	Quality criteria
Tancitaro Tan2	19.42	102.30	Michoacan-Guanajuato	209	41	8	354	44	199	3.9	82	218	N	Maciel Peña et al. (2009)	
CB08	21.04	104.76	Ceboruco San-Pedro	215	26	7	31	59	197	4.8	58	303	N	Pétronille et al. (2005)	Disturbed
Col21	19.64	103.75	Colima	215	18	9	355	36	68	6.7	85	171	N	Garcia-Ruiz et al. (2016)	
TM1	20.79	103.85	Tequila	216	11	6	12	25	45	9.9	76	18	N	Rodriguez Ceja et al. (2006)	Quality criteria
TEP6	21.33	104.73	Ceboruco San-Pedro	220	36	7	148	-27	21	14.3	-59	338	T	Calvo-Rathert et al. (2013)	Quality criteria

Tacambaro Tac-18	19.22	101.56	Michoacan-Guanajuato	220	40	8	353	25	156	5.5	81	127	N	Maciel Peña et al. (2014)	
BH	19.43	102.16	Michoacan-Guanajuato	230	68	14	3	29	10	13.3	85	41	N	Michalk et al. (2013)	Quality criteria
DQ	19.49	97.15	Eastern TMVB	240	50	10	358	32	77	5.5	87	125	N	Michalk et al. (2013)	
MAS_16	20.57	104.89	Mascota	248	39	5	356	34	45	11.2	86	139	N	Garcia-Ruiz et al. (2017a)	Quality criteria
CB09	21.13	104.95	Ceboruco San-Pedro	250	20	3	42	64	15	18.6	48	299	N	Pétronille et al. (2005)	Quality criteria
Tancitaro Tan6	19.43	102.44	Michoacan-Guanajuato	256	18	7	59	18	41	9.6	32	349	N	Maciel Peña et al. (2009)	Quality criteria
BI	19.43	102.44	Michoacan-Guanajuato	256	9	12	20	35	20	9.9	71	345	N	Michalk et al. (2013)	Quality criteria
MAS_18	20.82	104.97	Mascota	257	24	8	3	36	91	5.19	87	1	N	Garcia-Ruiz et al. (2017a)	
MAS-20	20.82	104.97	Mascota	257	24	10	3	35	198	3.4	87	13	N	Maillol et al. (1997)	
Palpan, PA-05	18.84	99.46	Chichinautzin	260	20	8	354	24	387	4.7	82	124	N	This Study	
CU	20.88	103.90	Tequila	261	11	9	335	56	22	11.3	63	207	N	Michalk et al. (2013)	Quality criteria
TM6	20.88	103.90	Tequila	261	11	5	12	37	64	9.6	79	345	N	Rodriguez Ceja et al. (2006)	
CB05	21.15	104.63	Ceboruco San-Pedro	264	52	6	325	32	75	7.4	57	165	N	Pétronille et al. (2005)	Disturbed
CD	19.39	102.41	Michoacan-Guanajuato	269	11	12	2	24	142	3.7	83	62	N	Michalk et al. (2013)	
Iztaccihuatl, 1968-10	19.20	98.70	Popocatepetl area	270	20	6	7	29	199	4.8	82	19	N	Steele (1985)	
Iztaccihuatl, 1968-13	19.20	98.70	Popocatepetl area	270	20	7	356	32	569	2.5	86	146	N	Steele (1985)	
AH	19.14	100.18	Valle del Bravo	282	5	6	5	29	57	9.0	84	26	N	Michalk et al. (2013)	Quality criteria
AT	21.16	104.07	Ceboruco San-Pedro	283	5	10	351	34	105	5.0	81	151	N	Michalk et al. (2013)	
Col10	19.52	103.76	Colima	300	95	8	334	-43	32	8.6	39	107	N	Garcia-Ruiz et al. (2016)	Transitional
TEP5	21.28	104.68	Ceboruco San-Pedro	307	34	7	339	51	258	3.9	69	199	N	Calvo-Rathert et al. (2013)	
AF	19.20	100.22	Valle del Bravo	315	36	17	358	40	40	5.7	86	233	N	Michalk et al. (2013)	Quality criteria
Tacambaro Tac-09	19.13	101.48	Michoacan-Guanajuato	320	20	8	355	35	375	3.1	85	171	N	Maciel Peña et al. (2014)	
DT	19.33	97.45	Eastern TMVB	330	80	16	9	48	54	5.1	77	301	N	Michalk et al. (2013)	Quality criteria
Tancitaro Tan5	19.39	102.41	Michoacan-Guanajuato	339	23	2	349	41	111	5.5	79	191	N	Maciel Peña et al. (2009)	Quality criteria
CF	19.37	102.37	Michoacan-Guanajuato	339	11	8	7	34	74	6.5	83	353	N	Michalk et al. (2013)	
Iztaccihuatl, 1968-78	19.20	98.70	Popocatepetl area	340	90	7	1	28	243	3.9	86	69	N	Steele (1985)	
TM11	20.69	103.88	Tequila	343	38	6	356	48	63	8.7	81	234	N	Rodriguez Ceja et al. (2006)	
Tancitaro TAN_01	19.03	102.58	Michoacan-Guanajuato	347	50	8	354	31	92	5.16	84	146	N	Garcia-Ruiz et al. (2017b)	
CY	20.69	103.92	Tequila	354	15	11	324	38	61	5.9	57	174	N	Michalk et al. (2013)	Transitional
TM10	20.69	103.92	Tequila	354	15	3	291	33	23	14.5	25	177	T	Rodriguez Ceja et al. (2006)	Quality criteria
BJ	19.28	102.39	Michoacan-Guanajuato	360	30	15	7	33	147	3.2	83	358	N	Michalk et al. (2013)	
EL	20.83	104.00	Tequila	362	13	15	358	36	56	5.1	88	142	N	Michalk et al. (2013)	Quality criteria
TM9	20.83	103.99	Tequila	362	13	9	23	6	222	6.2	61	22	T	Rodriguez Ceja et al. (2006)	Transitional
20-El Pelón	19.30	101.92	Michoacan-Guanajuato	370	50	7	348	24	63	7.7	77	140	N	Conte-Fasano et al. (2006)	
Col15	19.57	103.68	Colima	372	8	7	359	35	67	7.4	89	150	N	Garcia-Ruiz et al. (2016)	
CJ	19.31	102.54	Michoacan-Guanajuato	373	30	11	8	34	37	7.6	82	351	N	Michalk et al. (2013)	Quality criteria
Tancitaro Tan7	19.31	102.54	Michoacan-Guanajuato	373	61	6	349	28	115	6.3	79	146	N	Maciel Peña et al. (2009)	
Tancitaro TAN_07	19.28	102.38	Michoacan-Guanajuato	374	31	6	13	34	47	8.34	78	349	N	Garcia-Ruiz et al. (2017b)	Quality criteria
Tacambaro Tac-03A	19.09	101.56	Michoacan-Guanajuato	380	10	8	353	42	129	5.9	82	208	N	Maciel Peña et al. (2014)	
Tacambaro Tac-03B	19.09	101.56	Michoacan-Guanajuato	380	10	8	354	53	298	3.9	75	239	N	Maciel Peña et al. (2014)	
MAS_15	20.56	104.87	Mascota	385	35	5	57	5	326	6.5	32	355	T	Garcia-Ruiz et al. (2017a)	Transitional
MAS-1	20.55	104.87	Mascota	385	35	8	2	-4	221	3.7	67	70	N	Maillol et al. (1997)	Transitional
CO	19.26	102.36	Michoacan-Guanajuato	385	20	12	357	33	166	3.4	87	144	N	Michalk et al. (2013)	
C3-B Ajusco	19.43	99.13	Chichinautzin	390	160	13	0	17	18	9.9	79	81	N	Mora-Alvarez et al. (1991)	Quality criteria
C3-A Ajusco	19.43	99.13	Chichinautzin	390	160	14	124	0	111	3.8	-32	338	T	Mora-Alvarez et al. (1991)	Transitional
Ajusco JH	19.22	99.27	Chichinautzin	390	160	8	343	22	371	2.9	72	148	N	Morales et al. (2001)	
EK	21.03	104.36	Ceboruco San-Pedro	403	15	7	5	50	115	5.6	79	279	N	Michalk et al. (2013)	
CB03	21.03	104.36	Ceboruco San-Pedro	403	15	7	12	41	84	6.7	79	331	N	Pétronille et al. (2005)	
Iztaccihuatl, 1968-11	19.20	98.70	Popocatepetl area	410	140	7	4	24	168	4.7	82	51	N	Steele (1985)	
Iztaccihuatl, 1968-18	19.20	98.70	Popocatepetl area	410	140	7	17	53	66	7.5	69	304	N	Steele (1985)	
Iztaccihuatl, 1968-20	19.20	98.70	Popocatepetl area	410	140	7	23	61	158	4.8	60	297	N	Steele (1985)	
Iztaccihuatl, 1968-21	19.20	98.70	Popocatepetl area	410	140	7	352	32	132	5.3	82	159	N	Steele (1985)	
Iztaccihuatl, 1968-24	19.20	98.70	Popocatepetl area	410	140	7	355	21	82	6.7	80	112	N	Steele (1985)	
Iztaccihuatl, 1968-25	19.20	98.70	Popocatepetl area	410	140	6	27	62	328	3.7	57	299	N	Steele (1985)	
AR	21.23	104.79	Ceboruco San-Pedro	415	130	12	14	24	34	7.5	74	16	N	Michalk et al. (2013)	Quality criteria
CR	20.87	103.84	Tequila	416	3	14	0	27	78	4.5	83	76	N	Michalk et al. (2013)	
TL2	20.84	103.83	Tequila	416	3	6	342	21	63	8.5	70	139	N	Rodriguez Ceja et al. (2006)	
BD	19.38	102.09	Michoacan-Guanajuato	429	32	14	14	36	32	6.9	77	343	N	Michalk et al. (2013)	Quality criteria
Tancitaro Tan3	19.37	102.08	Michoacan-Guanajuato	429	64	8	340	61	242	3.6	62	226	N	Maciel Peña et al. (2009)	
CB12	21.11	104.70	Ceboruco San-Pedro	441	74	4	359	47	33	12.6	83	248	N	Pétronille et al. (2005)	Quality criteria
MAS-13	20.46	104.86	Mascota	497	19	9	14	19	878	1.7	73	22	N	Maillol et al. (1997)	
MAS_17	20.46	104.85	Mascota	497	19	5	3	6	348	4.2	72	65	N	Garcia-Ruiz et al. (2017a)	
Tacambaro Tac-25	19.00	101.38	Michoacan-Guanajuato	510	40	8	346	23	58	8.1	75	143	N	Maciel Peña et al. (2014)	Quality criteria
CB11	21.07	104.71	Ceboruco San-Pedro	512	34	1	5	53	273	6.9	77	274	N	Pétronille et al. (2005)	Quality criteria
AQ	21.20	104.79	Ceboruco San-Pedro	520	25	16	15	15	183	2.7	70	26	N	Michalk et al. (2013)	
CB06	21.20	104.78	Ceboruco San-Pedro	520	25	8	8	11	696	2.5	73	48	N	Pétronille et al. (2005)	
CB02	21.03	104.38	Ceboruco San-Pedro	521	15	6	25	58	56	10.5	62	301	N	Pétronille et al. (2005)	Quality criteria
Tacambaro Tac-14	19.19	101.65	Michoacan-Guanajuato	530	10	7	356	29	23	11.0	85	125	N	Maciel Peña et al. (2014)	Quality criteria
13-Yahuarato	19.62	101.57	Michoacan-Guanajuato	540	70	6	184	-29	950	2.2	-84	215	T	Conte-Fasano et al. (2006)	Transitional
qcrROD	19.59	101.58	Michoacan-Guanajuato	540	70	10	189	-43	46	6.5	-80	134	R	Ruiz-Martinez et al. (2010)	Quality criteria
23-Buenavista Tomatlán	19.14	102.55	Michoacan-Guanajuato	540	80	12	3	17	292	2.5	79	62	N	Conte-Fasano et al. (2006)	
TEP4	21.25	104.69	Ceboruco San-Pedro	542	24	5	136	-41	86	9.4	-49	357	T	Calvo-Rathert et al. (2013)	Transitional
qcnAGU	19.38	102.24	Michoacan-Guanajuato	550	60	9	10	32	30	8.5	80	358	N	Ruiz-Martinez et al. (2010)	Quality criteria
VAL1	19.60	101.54	Michoacan-Guanajuato	560	70	8	174	-28	190	4.8	-83	310	T	Maciel Peña et al. (2011)	Transitional
MAS_19	20.82	104.97	Mascota	568	30	8	5	22	618	1.99	79	47	N	Garcia-Ruiz et al. (2017a)	
MAS_06	20.42	104.70	Mascota	576	8	5	8	50	68	9.5	77	289	N	Garcia-Ruiz et al. (2017a)	
VAL12	19.14	102.55	Michoacan-Guanajuato	580	90	7	353	25	66	8.3	81	127	N	Maciel Peña et al. (2011)	
Iztaccihuatl, 1967-133	19.20	98.70	Popocatepetl area	580	110	6	10	26	208	4.7	79	20	N	Steele (1985)	
Iztaccihuatl, 1968-27	19.20	98.70	Popocatepetl area	580	110	6	354	30	80	7.6	84	144	N	Steele (1985)	
Tacambaro Tac-05	19.12	101.53	Michoacan-Guanajuato	590	440	8	353	43	917	2.2	81	212	N	Maciel Peña et al. (2014)	
EO	20.90	103.73	Tequila	592	20	11	172	-21	17	11.3	-77	295	T	Michalk et al. (2013)	Quality criteria
TL9	20.90	103.73	Tequila	592	20	1	342	9	111	5.5	66	126	N	Rodriguez Ceja et al. (2006)	Quality criteria
Tacambaro Tac-10	19.11	101.43	Michoacan-Guanajuato	600	50	7	354	29	76	6.8	83	137	N	Maciel Peña et al. (2014)	
EB	21.16	104.71	Ceboruco San-Pedro	601	6	9	8	40	39	8.3	82	332	N	Michalk et al. (2013)	Quality criteria
TM5	20.91	103.89	Tequila	604	3	7	340	24	84	9.4	69	146	N	Rodriguez Ceja et al. (2006)	
CK	19.26	102.58	Michoacan-Guanajuato	612	20	6	18	13	14	18.6	68	21	N	Michalk et al. (2013)	Quality criteria
Tancitaro Tan9	19.27	102.57	Michoacan-Guanajuato	612	41	8	353	31	39	9.2	83	148	N	Maciel Peña et al. (2009)	Quality criteria
Tancitaro Tan8	19.26	102.56	Michoacan-Guanajuato	612	41	8	28	3	359	2.9	57	17	N	Maciel Peña et al. (2009)	Disturbed
EF	21.15	104.67	Ceboruco San-Pedro	614	16	7	355	10	16	15.8	73	93	N	Michalk et al. (2013)	Quality criteria
CB04	21.07	104.65	Ceboruco San-Pedro	614	16	6	179	-42	64	8.8	-87	59	T	Pétronille et al. (2005)	Transitional
TM8	20.78	103.01	Tequila	619	8	6	357	27	79	7.6	83	101	N	Rodriguez Ceja et al. (2006)	
Tacambaro Tac-24	19.24	101.46	Michoacan-Guanajuato	620	30	8	349	45	198	4.3	78	207	N	Maciel Peña et al. (2014)	
TL3	20.85	103.86	Tequila	622	3	7	357	18	82	9.5	78	91	N	Rodriguez Ceja et al. (2006)	
CB13	21.14	104.70	Ceboruco San-Pedro	623	91	8	161	-34	48	8.5	-72	341	N	Pétronille et al. (2005)	Quality criteria
ED	21.14	104.70	Ceboruco San-Pedro	623	91	11	359	17	30	8.5	78	80	N	Michalk et al. (2013)	Quality criteria
TL12	20.86	103.98	Tequila	632	8	4	343	21	33	14.2	71	137	N	Rodriguez Ceja et al. (2006)	Quality criteria
CW	20.86	103.98	Tequila	632	8	10	5	27	122	4.4	82	39	N	Michalk et al. (2013)	
MAS_04	20.49	104.79	Mascota	635	11	8	332	56	142	4.18	61	205	N	Garcia-Ruiz et al. (2017a)	
TL4	20.89	103.94	Tequila	642	6	5	2	27	53	11.5	83	60	N	Rodriguez Ceja et al. (2006)	Quality criteria
MAS_05	20.49	104.79	Mascota	661	8	5	355	67	32	11.9	61	249	N	Garcia-Ruiz et al. (2017a)	Quality criteria
qcnAHOR	19.36	100.32	Michoacan-Guanajuato	670	70	8	313	19	291	2.9	44	165	T	Ruiz-Martinez et al. (2010)	Transitional
TL10	20.90	103.74	Tequila	671	13	8	164	21	107	6.4	-55	284	T	Rodriguez Ceja et al. (2006)	Disturbed
EN	20.90	103.73	Tequila	671	12	10	210	-33	52	6.7	-62	167	T	Michalk et al. (2013)	Quality criteria
CG	19.42	102.48	Michoacan-Guanajuato	673	10	9	231	-43	20	11.8	-43	151	T	Michalk et al. (2013)	Quality criteria
TO2	19.29	99.34	Sierra de Las Cruces	680	280	9	2	32	170	4	87	36	T	Osete et al. (2000)	Transitional
TL7	20.79	103.71	Tequila	691	26	6	344	39	52	8.7	75	174	N	Rodriguez Ceja et al. (2006)	Quality criteria
CQ	20.79	103.41	Tequila	691	26	10	2	28	87	5.2	84	58	N	Michalk et al. (2013)	
AZ	19.44	102.02	Michoacan-Guanajuato	730	113	10	10	45	21	10.9	78	308	T	Michalk et al. (2013)	Quality criteria
Tacambaro Tac-15	19.21	101.58	Michoacan-Guanajuato	730	20	6	352	21	254	5.4	79	122	N	Maciel Peña et al. (2014)	
VAL15 Jaripeo	19.84	100.75	Michoacan-Guanajuato	750	150	3	355	63	34	12.6	65	251	N	Maciel Peña et al. (2011)	Quality criteria
VAL16 Jaripeo	19.84	100.75	Michoacan-Guanajuato	750	150	5	349	33	47	9.8	79	161	N	Maciel Peña et al. (2011)	Quality criteria
Tancitaro TAN_06	19.27	102.37	Michoacan-Guanajuato	768	14	6	344	20	78	6.46	72	140	N	Garcia-Ruiz et al. (2017b)	
MAS_08	20.53	104.76	Mascota	780	0	4	300	-52	71	11	12	123	T	Garcia-Ruiz et al. (2017a)	Transitional
TS	18.40	95.20	Los Tuxtlas	800	100	10	2	18	86	5.2	81	73	N	Alva-Valdivia et al. (2001)	
TP	18.40	95.10	Los Tuxtlas	800	100	7	359	37	79	6.3	88	243	N	Alva-Valdivia et al. (2001)	
Jorullo JO-07	18.95	101.72	Michoacan-Guanajuato	810	10	9	172	-31	178	4.5	-82	333	R	Maciel Peña et al. (2014)	
AW	19.46	102.06	Michoacan-Guanajuato	815	13	14	165	-24	51	5.6	-74	325	R	Michalk et al. (2013)	Quality criteria
CB10	21.14	104.82	Ceboruco San-Pedro	819	25	8	332	-64	216	4.6	19	95	T	Pétronille et al. (2005)	Transitional
12-Cerro Sanambo	19.63	101.44	Michoacan-Guanajuato	870	50	12	181	-23	177	3.3	-82	251	R	Conte-Fasano et al. (2006)	
qcrCSA	19.63	101.44	Michoacan-Guanajuato	870	50	8	179	-23	291	2.9	-82	266	R	Ruiz-Martinez et al. (2010)	
BV	19.03	100.15	Valle del Bravo	881	189	10	357	12	185	3.6	77	93	N	Michalk et al. (2013)	
CE	19.26	102.25	Michoacan-Guanajuato	909	11	13	187	-32	42	6.5	-83	183	R	Michalk et al. (2013)	Quality criteria
MAS_10	20.49	104.88	Mascota	915	48	5	175	-19	29	14.3	-78	280	R	Garcia-Ruiz et al. (2017a)	Quality criteria
Tancitaro TAN_03	19.13	102.40	Michoacan-Guanajuato	925	135	6	10	51	17	7.94	75	291	N	Garcia-Ruiz et al. (2017b)	Quality criteria

Jorullo JO-15	18.94	101.77	Michoacan-Guanajuato	930	120	7	167	-29	246	3.8	-77	335	R	Maciel Peña et al. (2014)	
AN	19.15	100.03	Valle del Bravo	949	37	10	349	28	35	8.3	79	150	N	Michalk et al. (2013)	Quality criteria
TL11	20.85	103.76	Tequila	949	68	8	209	-28	122	8.3	-62	174	R	Rodriguez Ceja et al. (2006)	
CI	19.37	102.49	Michoacan-Guanajuato	957	157	13	15	52	16	10.6	71	300	N	Michalk et al. (2013)	Quality criteria
Tancitaro TAN_05	19.37	102.49	Michoacan-Guanajuato	957	157	7	36	75	189	4.4	41	279	N	Garcia-Ruiz et al. (2017b)	Disturbed
Tacambaro Tac-13	19.17	101.57	Michoacan-Guanajuato	960	70	8	358	38	81	6.6	87	218	N	Maciel Peña et al. (2014)	
Acatlan CHP-636-A	20.36	103.57	Michoacan-Guanajuato	970	130	9	162	-13	203	3.61	-68	311	R	Delgado-Granados et al. (1995)	
DE	18.85	100.13	Valle del Bravo	995	120	6	353	15	20	15.5	77	112	N	Michalk et al. (2013)	Quality criteria
SRG8	18.35	94.90	Los Tuxtlas	1000	100	9	172	-43	166	4.3	-80	38	R	Alva-Valdivia et al. (2001)	
Atlacholoaya AT-7	18.69	99.23	Chichinautzin	1020	160	8	3	58	227	6.1	70	268	N	This Study	
Jorullo JO-17	19.01	101.83	Michoacan-Guanajuato	1030	20	7	178	-31	81	7.4	-87	298	R	Maciel Peña et al. (2014)	
DH	19.39	100.02	Valle del Bravo	1049	81	3	185	-25	541	5.3	-82	222	R	Michalk et al. (2013)	
Jumatan-1	21.65	105.04	Michoacan-Guanajuato	1050	110	9	183	-32	156	4.1	-85	221	R	Goguitchaichvili et al. (2002)	
CN	19.47	102.56	Michoacan-Guanajuato	1075	34	10	23	25	52	6.8	67	360	N	Michalk et al. (2013)	Quality criteria
AO	19.17	100.12	Valle del Bravo	1095	105	8	4	-18	82	6.2	61	72	T	Michalk et al. (2013)	Transitional
TM4	20.91	103.98	Tequila	1121	149	5	208	-46	65	10.6	-64	146	R	Rodriguez Ceja et al. (2006)	
TM7	20.83	104.04	Tequila	1130	159	4	179	-17	80	13.8	-78	261	R	Rodriguez Ceja et al. (2006)	
4-Cerro Camatarán	20.19	101.52	Michoacan-Guanajuato	1170	140	5	165	-38	13	22.3	-76	356	R	Conte-Fasano et al. (2006)	Quality criteria
Maar San Nicolas M-05	20.39	101.23	Michoacan-Guanajuato	1180	170	6	307	45	10	14.8	41	187	T	Uribe-Cifuentes & Urrutia-Fucugauchi (1999)	Quality criteria
VAL8 San Nicolas	20.39	101.26	Michoacan-Guanajuato	1200		6	355	22	28	11.7	80	108	N	Maciel Peña et al. (2011)	Age; Quality criteria
Villa Guerrero SH-06	18.89	99.65	Chichinautzin	1200	50	7	178	-34	1495	3.2	-88	343	R	This Study	
9, Sierra de Las Cruces	19.31	99.31	Sierra de Las Cruces	1280	540	7	183	-34	196	4.3	-87	184	R	Mejia et al. (2005)	
Valsequillo basin, Blackish ash	18.92	98.16	Popocatepetl area	1290	20	6	265	13	99	6.7	-3	180	T	Goguitchaichvili et al. (2009)	Transitional
Valsequillo basin, Cerro Toluquilla	18.91	98.15	Popocatepetl area	1290	20	10	354	-11	113	4.6	65	96	T	Feinberg et al. (2009)	Disturbed
Valsequillo basin, Avila Camacho	18.91	98.18	Popocatepetl area	1290	20	8	190	-36	891	2.2	-81	164	R	Goguitchaichvili et al. (2009)	
Valsequillo basin, White Ashfall	18.92	98.17	Popocatepetl area	1290	20	6	1	33	654	2.6	89	36	N	Goguitchaichvili et al. (2009)	
Valsequillo basin, Toluquilla	18.91	98.15	Popocatepetl area	1290	20	8	170	-30	93	5.8	-80	337	R	Goguitchaichvili et al. (2009)	
Valsequillo basin, Cerro Toluquilla	18.91	98.15	Popocatepetl area	1290	20	12	176	-33	101	4.3	-86	339	R	Feinberg et al. (2009)	
Valsequillo basin, Xalnene tuff	18.92	98.16	Popocatepetl area	1300	30	10	281	18	52	6.8	13	177	T	Goguitchaichvili et al. (2009)	Quality criteria
Valsequillo basin, Xalnene tuff, VXT-V	18.92	98.16	Popocatepetl area	1300	30	8	206	-31	27	10.9	-65	173	R	Urrutia-Fucugauchi et al. (2012)	Quality criteria
Valsequillo basin, Xalnene tuff, Lapilli	18.92	98.16	Popocatepetl area	1300	30	20	205	-48	6	14.9	-65	143	R	Feinberg et al. (2009)	Quality criteria
Valsequillo basin, Xalnene tuff, VXT-IV	18.92	98.16	Popocatepetl area	1300	30	5	196	-25	82	8.5	-74	190	R	Urrutia-Fucugauchi et al. (2012)	
Valsequillo basin, Xalnene tuff, Bulk	18.92	98.16	Popocatepetl area	1300	30	5	194	-32	147	6.4	-77	176	R	Renne et al. (2005)	
BZ	19.04	100.08	Valle del Bravo	1322	100	14	194	-19	74	4.6	-74	202	R	Michalk et al. (2013)	
Santa Cruz CHP-538	20.49	103.52	Michoacan-Guanajuato	1390	470	9	153	-30	479	2.35	-64	341	R	Delgado-Granados et al. (1995)	
SRG6	18.20	94.85	Los Tuxtlas	1400	200	6	174	-30	72	7.0	-84	336	R	Alva-Valdivia et al. (2001)	
MAS_12	20.43	104.79	Mascota	1416	8	4	197	-32	65	8.6	-74	173	R	Garcia-Ruiz et al. (2017a)	
12, Sierra de Las Cruces	19.28	99.28	Sierra de Las Cruces	1430	170	10	161	-43	153	3.9	-72	12	R	Mejia et al. (2005)	
18, Nevado de Toluca	19.17	99.81	Sierra de Las Cruces	1490	510	5	178	-17	968	2.5	-79	271	R	Mejia et al. (2005)	
VL	18.30	94.70	Los Tuxtlas	1500	200	5	232	-18	36	12.3	-39	178	R	Alva-Valdivia et al. (2001)	Quality criteria
qcnCOP	19.29	100.35	Michoacan-Guanajuato	1500	300	8	357	21	400	2.8	81	99	N	Ruiz-Martinez et al. (2010)	
Tacambaro Tac-06	19.21	101.48	Michoacan-Guanajuato	< 5		8	334	23	146	5.1	64	156	N	Maciel Peña et al. (2014)	Age
Los Cardos	19.09	99.26	Chichinautzin	<10		8	356	39	96	5.6	85	210	N	This Study	Age
2-Cerro Gordo	20.40	100.97	Michoacan-Guanajuato	> 40		8	5	33	88	5.9	85	15	N	Conte-Fasano et al. (2006)	Age
Huilote 2	19.03	99.30	Chichinautzin	>10		8	4	23	277	3.3	82	52	N	Morales et al. (2001)	Age
Huilote 1	19.03	99.27	Chichinautzin	>10		8	14	11	353	3.0	71	34	N	Morales et al. (2001)	Age
Acopiaxco JJ	19.11	99.18	Chichinautzin	>14		13	353	33	498	1.9	83	162	N	Morales et al. (2001)	Age
Cilcuayo MMA-79-B	19.14	98.97	Chichinautzin	>18,7		8	358	20	223	6.2	81	94	N	This Study	Age
Chinconquiat A3	19.21	98.86	Chichinautzin	>31		8	349	21	209	8.5	77	135	N	This Study	Age
Basuroro	19.43	99.13	Michoacan-Guanajuato	Brunhes		10	346	28	451	2.3	76	154	T	Rosas Elguera & Urrutia-Fucugauchi (1992)	Age; Transitional
Villamar	19.43	99.13	Michoacan-Guanajuato	Brunhes		12	350	29	54	6.0	80	150	T	Rosas Elguera & Urrutia-Fucugauchi (1992)	Age; Quality criteria
P92	21.8	171.2	Popocatepetl area	Brunhes		4	291	13	57	12.3	22	97	T	Conte-Fasano et al. (2004)	Age; Quality criteria
P1	21.8	171.2	Popocatepetl area	Brunhes		9	4	36	229	3.4	86	304	N	Conte-Fasano et al. (2004)	Age
P3	21.8	171.2	Popocatepetl area	Brunhes		5	325	33	333	4.2	57	99	N	Conte-Fasano et al. (2004)	Age
P5	21.8	171.2	Popocatepetl area	Brunhes		4	351	33	183	6.8	81	76	N	Conte-Fasano et al. (2004)	Age
P7	21.8	171.2	Popocatepetl area	Brunhes		5	1	6	591	3.2	71	6	N	Conte-Fasano et al. (2004)	Age
P8	21.8	171.2	Popocatepetl area	Brunhes		5	332	54	122	6.9	62	132	N	Conte-Fasano et al. (2004)	Age
P10	21.8	171.2	Popocatepetl area	Brunhes		6	314	52	137	5.7	48	124	N	Conte-Fasano et al. (2004)	Age
P11	21.8	171.2	Popocatepetl area	Brunhes		7	348	38	148	5.0	79	99	N	Conte-Fasano et al. (2004)	Age
P122	21.8	171.2	Popocatepetl area	Brunhes		4	47	52	107	8.9	47	254	N	Conte-Fasano et al. (2004)	Age
P13	21.8	171.2	Popocatepetl area	Brunhes		8	345	30	200	3.9	75	80	N	Conte-Fasano et al. (2004)	Age
P14	21.8	171.2	Popocatepetl area	Brunhes		9	348	49	80	5.8	77	138	N	Conte-Fasano et al. (2004)	Age
P15	21.8	171.2	Popocatepetl area	Brunhes		4	360	28	67	11.3	83	9	N	Conte-Fasano et al. (2004)	Age
P16	21.8	171.2	Popocatepetl area	Brunhes		8	2	27	164	4.3	83	355	N	Conte-Fasano et al. (2004)	Age
22	21.8	171.2	Popocatepetl area	Brunhes		5	315	6	11	24.2	43	82	T	Conte-Fasano et al. (2004)	Age; Quality criteria
3	21.8	171.2	Popocatepetl area	Brunhes		6	332	46	119	6.1	64	117	N	Conte-Fasano et al. (2004)	Age
6	21.8	171.2	Popocatepetl area	Brunhes		4	332	30	83	10.1	63	92	N	Conte-Fasano et al. (2004)	Age
82	21.8	171.2	Popocatepetl area	Brunhes		6	306	70	19	15.9	38	151	T	Conte-Fasano et al. (2004)	Age; Quality criteria
9	21.8	171.2	Popocatepetl area	Brunhes		8	338	18	81	6.2	65	72	N	Conte-Fasano et al. (2004)	Age
10	21.8	171.2	Popocatepetl area	Brunhes		5	358	39	33	13.4	88	107	N	Conte-Fasano et al. (2004)	Age; Quality criteria
Moral	19.43	99.13	Michoacan-Guanajuato	Matuyama		8	346	32	231	3.6	77	164	N	Rosas Elguera & Urrutia-Fucugauchi (1992)	Age

1	Alva-Valdivia, L., Goguitchaichvili, A. & Urrutia-Fucugauchi, J.	2001	Further constraints for the Plio-Pleistocene geomagnetic field strength: New results from the Los Tuxtlas volcanic field (Mexico)	Earth Planets Space	53	873-881	https://doi.org/10.1186/BF03351684
2	Alva-Valdivia, L.	2005	Comprehensive paleomagnetic study of a succession of Holocene olivine-basalt flow: Xitle volcano (Mexico) revisited	Earth Planets Space	57	839-853	https://doi.org/10.1186/BF03351862
3	Böhnel, H. & Molina-Garza, R.	2002	Secular variation in Mexico during the last 40,000 years	Physics of the Earth and Planetary Interiors	133	99-109	https://doi.org/10.1016/S0031-9201(02)00095-X
4	Böhnel, H., Morales, J., Caballero, C. Alva, L., McIntosh, G., Gonzalez, S. & Sherwood, G.J.	1997	Variation of rock magnetic parameters and paleointensities over a single Holocene Lava flow	Journal of Geomagnetism and Geoelectricity	49	523-542	https://doi.org/10.5636/jgg.49.523
5	Böhnel, H., Pavon-Carrasco, F.J., Sieron, K. & Mahgoub, A.N.	2016	Palaeomagnetic dating of two recent lava flows from Ceboruco volcano, western Mexico	Geophysical Journal International	207	1203-1215	https://doi.org/10.1093/gji/ggw310
6	Calvo-Rathert, M., Aguilar-Reyes, B., Goguitchaichvili, A., Rosas Elguera, J., Franco, H., Morales, J., Soto, R., Carrancho, A. & Delgado, H.	2013	Rock-magnetic and paleomagnetic results from the Tepic-Zacoalco rift region (western Mexico)	Studia Geophysica et Geodaetica	57	309-331	https://doi.org/10.1007/s11200-012-0239-y
7	Cifuentes-Nava, G., Goguitchaichvili, A., Lopez-Loera, H., Cervantes, M., Cortes, A., Sanchez-Bettucci, L., Macias, J.L., Morales, J. & Rosas-Elguera, J.	2017	Full vector magnetic dating of some pyroclastic rocks associated to the Colima volcano, western Mexico	Boletin de la Sociedad Geologica Mexicana	69	577-590	https://www.jstor.org/stable/26461916
8	Clement, B.M., Connor, C.B. & Graper, G.	1993	Paleomagnetic estimate of the emplacement temperature of the long-runout Nevado de Colima volcanic debris avalanche deposit, Mexico	Earth and Planetary Science Letters	120	499-510	https://doi.org/10.1016/0012-821X(93)90260-G
9	Conte-Fasano, G., Urrutia-Fucugauchi, J., Goguitchaichvili, A., Soler-Arechalde, A.M. & Morton-Bermea, O.	2004	Paleomagnetic study of Lavas from the Popocatepetl Volcanic Region, Central Mexico	International Geology Review	46	210-225	https://doi.org/10.2747/0020-6814.46.3.210
10	Conte-Fasano, G., Urrutia-Fucugauchi, J., Goguitchaichvili, A. & Morales-Contreras, J.	2006	Low-latitude paleosecular variation and the time-averaged field during the late Pliocene and Quaternary—Paleomagnetic study of the Michoacan-Guanajuato volcanic field, Central Mexico	Earth Planets Space	58	1359-1371	https://doi.org/10.1186/BF03352632
11	Delgado-Granados, H., Urrutia-Fucugauchi, J., Hasenaka, T. & Ban, M.	1995	Southwestward volcanic migration in the western trans-Mexican volcanic belt during the last 2 Ma	Geofisica Internacional	34	341-352	
12	Feinberg, J.M., Renne, P.R., Arroyo-Cabrales, J., Waters, M.R., Ochoa-Castillo, P. & Perez-Campa, M.	2009	Age constraints on alleged "footprints" preserved in the Xalnene tuff near Puebla, Mexico	Geology	37	267-270	https://doi.org/10.1130/G24913A.1
13	Garcia-Quintana, A., Goguitchaichvili, A., Morales, J., Cervantes-Solano, M., Osorio-Ocampo, S., Macias, J.L. & Urrutia-Fucugauchi, J.	2016	Datación magnética de rocas volcánicas formadas durante el Holoceno: caso de flujos de lava alrededor del Lago de Pátzcuaro (campo volcánico Michoacán-Guanajuato)	Revista Mexicana de Ciencias Geologicas	33	209-220	
14	Garcia-Ruiz, R., Goguitchaichvili, A., Cervantes-Solano, M., Cortes-Cortes, A., Morales-Contreras, J., Maciel-Peña, R., Rosas-Elguera, J. & Macias-Vazquez, J.L.	2016	Secular variation and excursions of the Earth magnetic field during the Plio-Quaternary: New paleomagnetic data from radiometrically dated lava flows of the Colima volcanic complex (western Mexico)	Revista Mexicana de Ciencias Geologicas	33	72-80	
15	Garcia-Ruiz, R., Goguitchaichvili, A., Cervantes-Solano, M., Morales, J., Maciel-Peña, R., Rosas-Elguera, J., Cejudo-Ruiz, R. & Urrutia-Fucugauchi, J.	2017	Rock-magnetic and paleomagnetic survey on dated lava flows erupted during the Brunhes and Matuyama chrons: the Mascota Volcanic Field revisited (Western Mexico)	Studia Geophysica et Geodaetica	61	249-263	https://doi.org/10.1007/s11200-016-0148-6
16	Garcia-Ruiz, R., Goguitchaichvili, A., Lopez-Loera, H., Cervantes-Solano, M., Urrutia-Fucugauchi, J., Morales-Contreras, J., Maciel-Peña, R. & Rosas-Elguera, J.	2017	Paleomagnetism and Aeromagnetic survey from Tancitaro volcano (Central Mexico) - Paleo-Secular Variation at low latitudes during the past 1 Ma	Geofisica Internacional	56	287-304	
17	Goguitchaichvili, A., Alva-Valdivia, L., Rosas-Elguera, J., Urrutia-Fucugauchi, J., Angel-Cervantes, M. & Caballero, C.	2002	Magnetic mineralogy, Palaeomagnetism, and Magnetostratigraphy of Nayarit volcanic formations (Western Mexico): a pilot study	International Geology Review	44	264-276	https://doi.org/10.2747/0020-6814.44.3.264
18	Goguitchaichvili, A., Martin del Pozzo, A.L., Rocha-Fernandez, J.L., Urrutia-Fucugauchi, J. & Soler-Arechalde, A.M.	2009	Paleomagnetic and rock-magnetic study on volcanic units of the Valsequillo Basin: implications for early human occupation in central Mexico	Earth Planets Space	61	205-211	https://doi.org/10.1186/BF03352900
19	Gonzalez, S., Sherwood, G., Böhnel, H. & Schnepp, E.	1997	Palaeosecular variation in Central Mexico over the last 30 000 years: the record from lavas	Geophysical Journal International	130	201-219	10.1111/j.1365-246X.1997.tb00999.x
20	Gratton, M.N., Goguitchaichvili, A., Conte, G., Shaw, J. & Urrutia-Fucugauchi, J.	2005	Microwave palaeointensity study of the Jorullo volcano (Central Mexico)	Geophysical Journal International	161	627-634	10.1111/j.1365-246X.2005.02619.x
21	Herrero, E. & Pal, S.	1978	Paleomagnetic study of Sierra de Chichinautzin, Mexico	Geofisica Internacional	17(2)	167-180	
22	Juarez-Arriaga, E., Böhnel, H., Carrasco-Nuñez, G & Mahgoub, A.N.	2018	Paleomagnetism of Holocene lava flows from Los Humeros caldera, eastern Mexico: Discrimination of volcanic eruptions and their age dating	Journal of South American Earth Sciences	88	736-748	https://doi.org/10.1016/j.jsames.2018.10.008
23	Maciel Peña, R., Goguitchaichvili, A., Garduño Monroy, V.H., Ruiz Martinez, V.C., Aguilar Reyes, B., Morales, J., Alva-Valdivia, L., Caballero Miranda, C. & Urrutia-Fucugauchi, J.	2009	Paleomagnetic and rock-magnetic survey of Brunhes lava flows from Tancitaro volcano, Mexico	Geofisica Internacional	48	375-384	
24	Maciel Peña, R., Goguitchaichvili, A., Henry, B., Sanchez-Bettucci, L., Morales, J., Aguilar-Reyes, B., Soler-Arechalde, A.M. & Calvo-Rathert, M.	2011	Plio-Pleistocene paleomagnetic record from the Michoacan-Guanajuato monogenetic volcanic field (western Mexico)	Studia Geophysica et Geodaetica	55	311-328	https://doi.org/10.1007/s11200-011-0017-2

25	Maciel Peña, R., Goguitchaichvili, A., Guilbaud, M.-N., Ruiz Martinez, V.C., Calvo Rathert, M., Siebe, C., Aguilar Reyes, B. & Morales, J.	2014	Paleomagnetic secular variation study of Ar–Ar dated lavas flows from Tacambaro area (Central Mexico): Possible evidence of Intra-Jaramillo geomagnetic excursion in volcanic rocks	Physics of the Earth and Planetary Interiors	229	98-109	https://doi.org/10.1016/j.pepi.2014.01.005
26	Mahgoub, A.N., Böhnel, H., Siebe, C. & Chevrel, M.O.	2017a	Paleomagnetic study of El Metate shield volcano (Michoacán, Mexico) confirms its monogenetic nature and young age (~ 1250 CE)	Journal of Volcanology and Geothermal Research	336	209-218	https://doi.org/10.1016/j.jvolgeores.2017.02.024
27	Mahgoub, A.N., Reyes-Guzman, N., Böhnel, H., Siebe, C., Pereira, G. & Dorison, A.	2017b	Paleomagnetic constraints on the ages of the Holocene Malpaís de Zacapu lava flow eruptions, Michoacán (México): Implications for archeology and volcanic hazards	The Holocene			https://doi.org/10.1177/0959683617721323
28	Maillol, J.M., Bandy, W.L. & Ortega-Ramirez, J.	1997	Paleomagnetism of Plio-Quaternary basalts in the Jalisco block, western Mexico	Geofisica Internacional	36	21-35	
29	Mejia, V., Böhnel, H., Opdyke, N.L., Ortega-Rivera, M.A., Lee, J.K.W. & Aranda-Gomez, J.J.	2005	Paleosecular variation and time-averaged field recorded in late Pliocene-Holocene lava flows from Mexico	Geochemistry Geophysics Geosystems	Q07H19		https://doi.org/10.1029/2004GC000871
30	Michalk, D.M., Biggin, A.J., Knudsen, M.F., Böhnel, H.N., Nowaczyk, N.R., Ownby, S. & Lopez-Martinez, M.	2010	Application of the multispecimen palaeointensity method to Pleistocene lava flows from the Trans-Mexican Volcanic Belt	Physics of the Earth and Planetary Interiors	179	139-156	https://doi.org/10.1016/j.pepi.2010.01.005
31	Michalk, D.M., Böhnel, H.N., Nowaczyk, N.R., Aguirre-Diaz, G.J., Lopez-Martinez, M., Ownby, S. & Negendank, J.F.W.	2013	Evidence for geomagnetic excursions recorded in Brunhes and Matuyama Chron lavas from the trans-Mexican volcanic belt	Journal of Geophysical Research	118	2648-2669	https://doi.org/10.1002/jgrb.50214
32	Mora Alvarez, G., Caballero Miranda, C., Urrutia Fucugauchi, J. & Uchiumi, Sh.	1991	Southward migration of volcanic activity in the Sierra de las Cruces, basin of Mexico? - A preliminary K-Ar dating and palaeomagnetic study	Geofisica Internacional	30	61-70	
33	Morales, J., Goguitchaichvili, A. & Urrutia-Fucugauchi, J.	2001	A rock-magnetic and paleointensity study of some Mexican volcanic lava flows during the Latest Pleistocene to the Holocene	Earth Planets Space	53	893-902	https://doi.org/10.1186/BF03351686
34	Osete, M.L., Ruiz-Martinez, V.C., Caballero, C., Galindo, C., Urrutia-Fucugauchi, J. & Tarling, D.H.	2000	Southward migration of continental volcanic activity in the Sierra de Las Cruces, Mexico: palaeomagnetic and radiometric evidence	Tectonophysics	318	201-215	https://doi.org/10.1016/S0040-1951(99)00312-1
35	Pétronille, M., Goguitchaichvili, A., Henry, B., Alva-Valdivia, L., Rosas-Elguera, J., Urrutia-Fucugauchi, J., Rodriguez Ceja, M. & Calvo-Rathert, M.	2005	Paleomagnetism of Ar-Ar dated lava flows from the Ceboruco-San Pedro volcanic field (western Mexico): Evidence for the Matuyama-Brunhes transition precursor and a fully reversed geomagentic event in the Brunhes chron	Journal of Geophysical Research	110(B8)		https://doi.org/10.1029/2004JB003321
36	Renne, P.R., Feinberg, J.M., Waters, M.R., Cabrales, J.A., Castillo, P.O., Campa, M.P. & Knight, K.B.	2005	Age of the Xalnene ash, Central Mexico, and archeological implications	Nature	438		https://doi.org/10.1038/nature04425
37	Rodriguez Ceja, M., Goguitchaichvili, A., Calvo-Rathert, M., Morales-Contreras, J., Alva-Valdivia, L., Rosas Elguera, J., Urrutia Fucugauchi, J. & Delgado Granados, H.	2006	Paleomagnetism of the Pleistocene Tequila Volcanic Field (Western Mexico)	Earth Planets Space	58	1349-1358	https://doi.org/10.1186/BF03352631
38	Rosas Elguera, J. & Urrutia-Fucugauchi, J.	1992	Magnetoestratigrafia volcanica de la zona geotermica Ixtlan de los Hervores-Los Negritos, Michoacan, Mexico: resultados preliminares	Geofisica Internacional	31	431-442	
39	Ruiz-Martinez, V.C., Urrutia-Fucugauchi, J. & Osete, M.L.	2010	Palaeomagnetism of the Western and Central sectors of the Trans-Mexican volcanic belt - implications for tectonic rotations and palaeosecular variation in the past 11 Ma	Geophysical Journal International	180	577-595	https://doi.org/10.1111/j.1365-246X.2009.04447.x
40	Steele, W.K.	1985	Paleomagnetic constraints on the volcanic history of Iztaccihuatl	Geofisica Internacional	24	159-167	
41	Uribe-Cifuentes, R.M. & Urrutia-Fucugauchi, J.	1999	Paleomagnetic study of the Valle de Santiago volcanics, Michoacan-Guanajuato volcanic field, Mexico	Geofisica Internacional	38	217-230	
42	Urrutia-Fucugauchi, J.	1996	Palaeomagnetic study of the Xitle-Pedregal de San Angel lava flow, southern Basin of Mexico	Physics of the Earth and Planetary Interiors	97	177-196	https://doi.org/10.1016/0031-9201(95)03136-7
43	Urrutia-Fucugauchi, J. & Martin del Pozzo, A.L.	1993	Implicaciones de los datos paleomagneticos sobre la edad de la Sierra de Chichinautzin, cuenca de Mexico	Geofisica Internacional	32	523-533	
44	Urrutia-Fucugauchi, J., Ramirez Negrete, A., Venegas Salgado, S., Sanchez Reyes, S., Delgado Granados, H., Campos Enriquez, J.O. & Moran Zenteno, D.J.	1988	Paleomagnetismo y magnetoestratigrafia de la Sierra de la Primavera, Jalisco	Geofisica Internacional	27	395-414	
45	Urrutia-Fucugauchi, J., Alva-Valdivia, L., Goguitchaichvili, A., Rivas, M.L. & Morales, J.	2004	Palaeomagnetic, rock-magnetic and microscopy studies of historic lava flows from the Paricutin volcano, Mexico: implications for the deflection of palaeomagnetic directions	Geophysical Journal International	156	431-442	10.1111/j.1365-246X.2004.02166.x
46	Urrutia-Fucugauchi, J., Trigo-Huesca, A. & Perez-Cruz, L.	2012	Magnetic links among lava flows, tuffs and the underground plumbing system in a monogenetic volcano, derived from magnetics and paleomagnetic study	Physics of the Earth and Planetary Interiors	212-213	10-18	https://doi.org/10.1016/j.pepi.2012.09.002
47	Vlag, P., Alva-Valdivia, L., de Boer, C.B., Gonzalez, S. & Urrutia-Fucugauchi, J.	2000	A rock- and paleomagnetic study of a Holocene lava flow in Central Mexico	Physics of the Earth and Planetary Interiors	118	259-272	https://doi.org/10.1016/S0031-9201(99)00158-2
48	Mahgoub, A.N., Juárez-Arriaga, E., Böhnel, H., Siebe, C. & Pavón-Carrasco, F.J.	2019	Late-Quaternary secular variation data from Mexican volcanoes	Earth and Planetary Science Letters	519	28-39	https://doi.org/10.1016/j.epsl.2019.05.001