Reconnaissance of Ignimbrites and Fall Deposits of the Guajara Group of the Bandas del Sur region, and the Diego Hernández Group, Las Cañadas Caldera, Tenerife.

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Abstract

Understanding the eruptive histories of volcanically active regions is essential for anticipating future hazards and assessing risk. Tenerife, a volcanic island off the northwestern coast of Africa and a part of the Canary Islands, has a complex geologic history. It hosts magma compositions ranging from basaltic to phonolitic, producing diverse eruptive styles, including explosive Plinian eruptions associated with pyroclastic density currents. While some explosive events are well-documented in the stratigraphic record, significant gaps remain, in part due to preservation bias favoring ignimbrite-forming eruptions. Through reconnaissance surveys and detailed stratigraphic logging of previously undocumented pumice fall deposits, we aim to refine the eruptive framework of Tenerife within eight different locations, including Washbasin Barranco, Volcán de Fasnia, and particularly within the lower Diego Hernández (DH) Group exposed along the Las Cañadas Caldera wall. Units below the Arico ignimbrite at Barranco Tamadaya and Washbasin Barranco appear to represent new ignimbrite sequences and pumice fall layers, while the Porís deposit is interpreted as part of the Eras Formation. The DH Group at the caldera wall revealed eight new pumice fall deposits and one flow unit, suggesting a smaller potential hiatus between the DH and Guajara Groups. Additional deposits in the Volcán de Fasnia correlate with Porís, La Caleta, and Abrigo Formations. Stratigraphy at La Tarta may represent a link to the Fasnia Formation. These findings show a more variable eruptive record than previously thought, with significant implications for hazard assessment and the volcanic evolutionary model of Tenerife.

Contents **4**

1.Introduction

1.1 Rationale for Study

Plinian explosive eruptions pose significant hazards to landscapes, infrastructure, and communities. Understanding the eruptive history of volcanically active regions is therefore essential for improving hazard assessments and anticipating future events. Tenerife, the largest island in the Canary archipelago, has experienced a long and complex history of explosive volcanism, including both Plinian and Strombolian eruptions. Over the past three decades, substantial stratigraphic work has been conducted across the island (Martí et al., 1994; Bryan et al., 1998; Brown et al., 2003; Edgar et al., 2007; Dávila Harris et al., 2009, 2023), yet the complete eruptive record remains unresolved. This is due in part to preservation bias: larger eruptions that produced voluminous pyroclastic flows are more likely to be preserved than smaller-scale pumice fall deposits (PFDs), which may have been more frequent but are easily eroded or obscured. Since 2021, ongoing studies by GeoIntern participants under the direction of Dr. Richard Brown have identified more than 40 previously undocumented minor PFDs across the Bandas del Sur region, correlating in age with the Guajara Formation (~670 ka; Fig. 1). Additional deposits potentially linked to the Diego Hernández (DH) Formation have also been documented (Hamilton, unpub. data). These discoveries suggest a more frequent eruptive record than previously documented.

Building upon work of previous GeoInterns, the key objectives of this study are to (1) identify and describe unknown pumice fall deposits, and (2) correlate these findings with existing stratigraphic records. Specifically, we aim to expand outwards from DH caldera wall and consolidate DH stratigraphy, and establish lower Guajara stratigraphy below the Arico formation (Fig. 1) through exploration of barrancos in Bandas del Sur in Southern Tenerife. Ultimately, this work will improve understanding of the frequency, scale, and hazards of Plinian eruptions associated with the Las Cañadas Caldera system over the past ~1.6 million years.

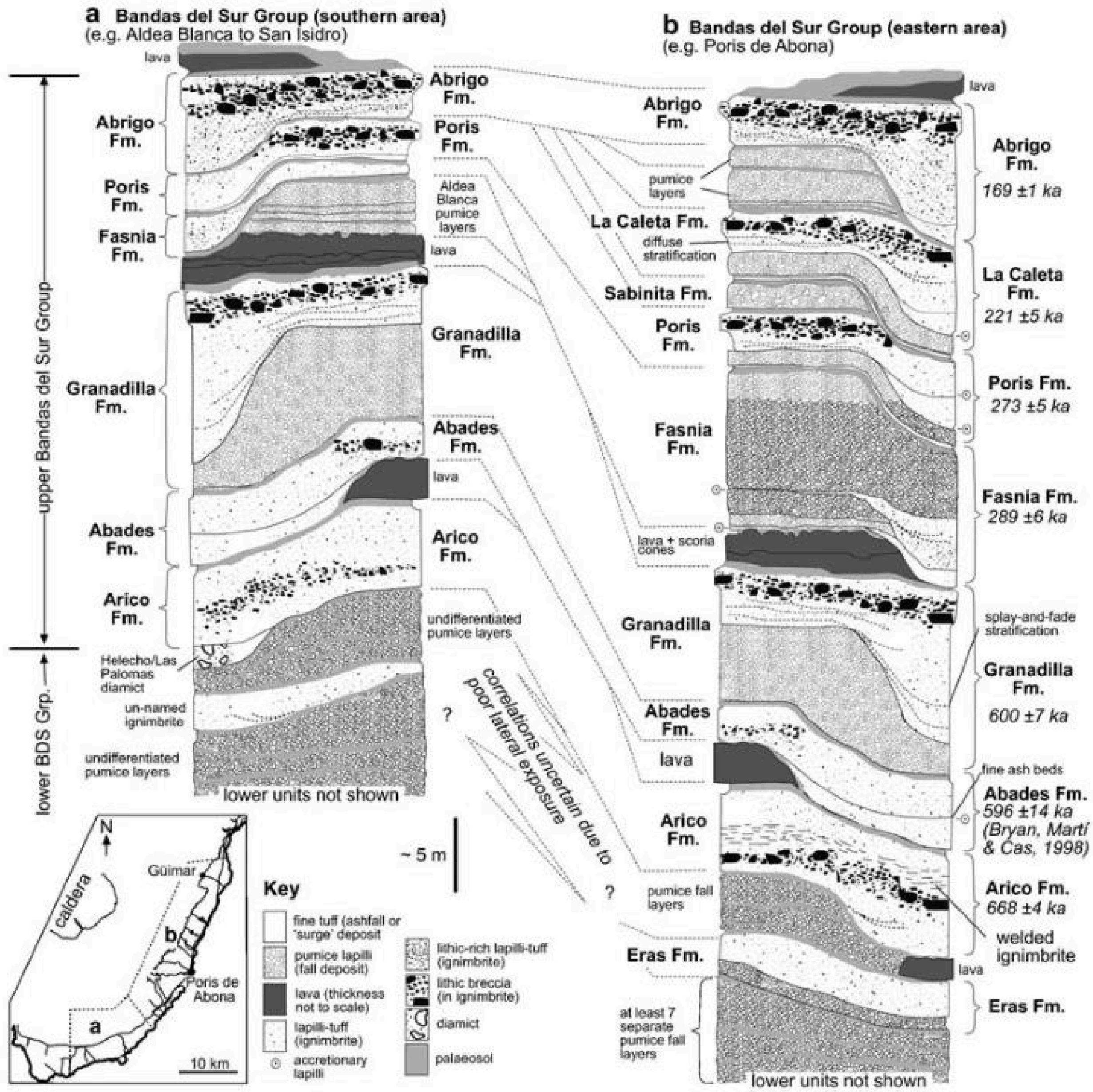

Figure 1: Stratigraphy of Bandas del Sur, SE Tenerife, including eruptive deposits of Guajara and Diego Hernandez age (Brown et al., 2003).

1.2 Geologic Setting

Tenerife is a geologically complex island with intraplate volcanism, located in the eastern Atlantic off the northwest African coast. It is part of the Canary Islands, believed to be formed by hotspot volcanism and is the second largest ocean island volcanic system after Hawai'i (Cas et al., 2022). Beginning at least ~12 million years ago, the island began forming as a basaltic shield volcano, sourced from a mantle plume. Over time, magmas interacted with the lithosphere and underwent fractional crystallization, becoming more evolved and phonolitic in composition (Cas et al., 2022). Around 3.05 Ma, as this phonolitic system continued to develop beneath central Tenerife, leading to the construction of the Las Cañadas Edifice and later the Las Cañadas Caldera, which formed from multiple collapse episodes.

The central volcanic complex of Tenerife is dominated by the Las Cañadas Caldera, which is one of the best exposed calderas in the world (Martí et al., 1994). The caldera is associated with three major eruptive cycles resulting in the Ucanca (~1.66-0.9Ma), Guajara (~0.85-0.57Ma), and Diego Hernández (>0.37-0.19Ma) groups (Cas et al., 2022). Each cycle produced large-scale pyroclastic deposits, caldera collapse events and intracaldera sequences (Martí et al., 1994).

Since approximately 175ka, two stratovolcanoes, Teide and Pico Viejo have been growing along the northern margin of the caldera, while basaltic volcanism has persisted along the island's flanks producing monogenetic eruptions (Cas et al., 2022). Tenerife's volcanic products span a range of eruptive styles, including basaltic shield eruptions, monogenetic eruptions, highly explosive Plinian eruptions, and pyroclastic flow generating events. This diversity of volcanic processes is recorded in the island's stratigraphy and highlights the complexity of reconstructing Tenerife's eruptive history. Continued study of minor PFDs provides key insights into the frequency and style of past eruptions and the evolving behavior of the Las Cañadas system.

2. Methods

To create a complete stratigraphic log, we selected locations around the island that had the potential to contain evidence of either a previously discovered plinian eruption or a new eruption (Fig. 2). We used distinctive "fingerprint" characteristics found in other deposits to place whether the deposits we were observing matched with a deposit observed in a different location. To set apart the different layers, we took note of the color, clast size, lithic content and color, lithic size, layer thickness, matrix content, angularity of clasts, and the grading of the contacts. We compared our observations in one location on the island to our observations in another location on the island to see if the characteristics of the ignimbrites and pumice layers corresponded with each other. In the Caldera, we walked along the scree slopes, brushing away ash to reveal the layers beneath, made observations using the same model we used in the barrancos, and then traced the layers horizontally along the caldera wall to determine whether the deposits were continuous.

Figure 2: Map of outcrop locations visited.

3.Results

Below, stratigraphic logs and descriptions of units found at sites visited are presented.

Full descriptions of pumice fall deposits and ignimbrites found are presented in the appendix.

3.1 Guajara Group, Bandas del Sur

3.1.1 Barranco Tamadaya

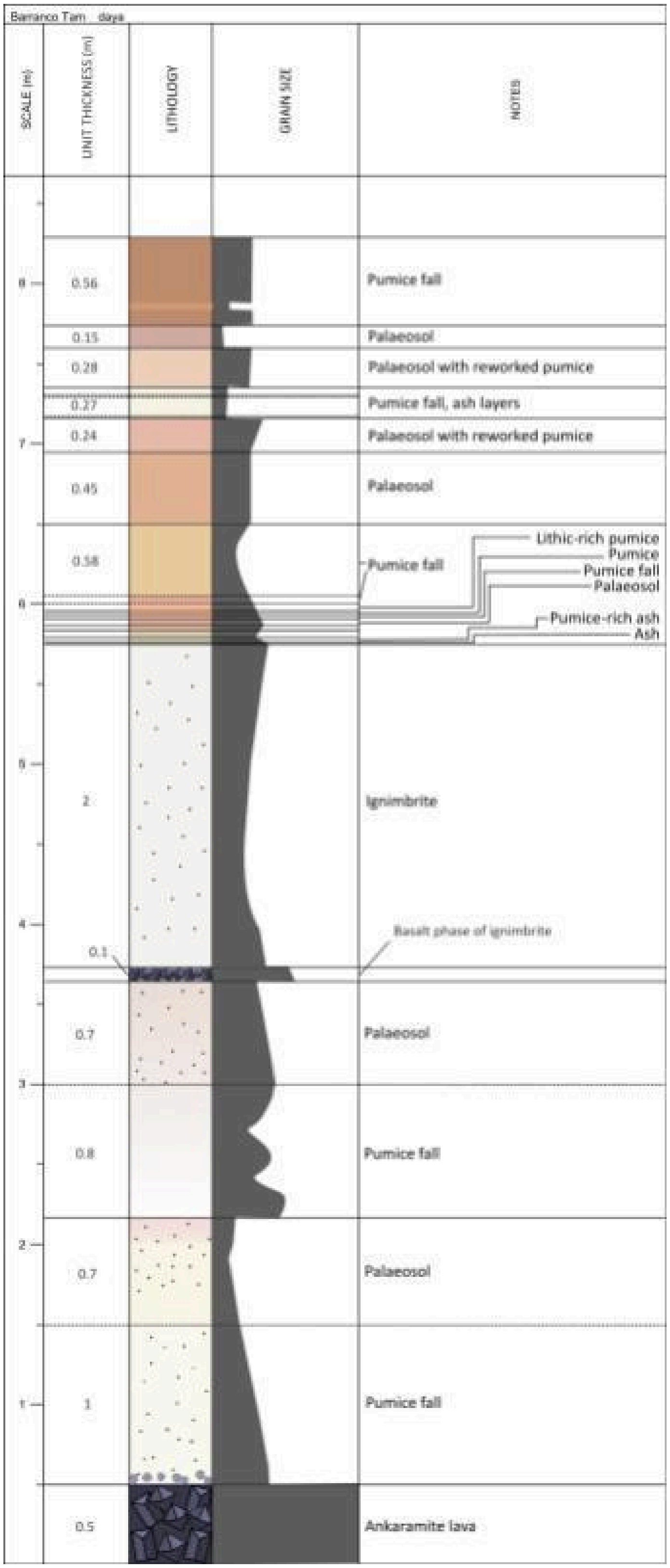

Figure 3: Stratigraphic log of units observed at Barranco Tamadaya.

The Barranco Tamadaya formation is exposed near the Area Recreativa el Contador and is stratigraphically below the Arico formation. At the type locality (Fig. 3), the first unit is 2 meters thick and moderately sorted, with angular and subangular pumice clasts that are smaller and less vesicular in the dark band of pumice. The second layer is an ignimbrite that is 2 meters thick and well graded, with poorly sorted blocks and bombs at the bottom, poorly sorted pebbles, lapilli, and pumice in the middle, and then chunks of grey pumice at the top. Following this is a PFD with angular, well sorted pumice in one layer and poorly sorted clasts in the next two layers.The next major pumice fall deposit is 0.51 meters thick, moderately sorted with angular pumice clasts that have small vesicles and contain phenocrysts and sanidines. The next pumice fall is 0.7 meters up, with the deposit being 0.18 meters thick, laterally continuous, and poorly sorted. After a 0.03 meter ash layer, the next pumice fall deposit is a 0.05 meter thick, moderately sorted, laterally continuous layer with angular cream and grey colored banded pumice. The final significant layer before the basalt flow is a pumice fall that is 0.56 meters thick, poorly sorted, and has varying thickness laterally.

3.1.2 Washbasin Barranco

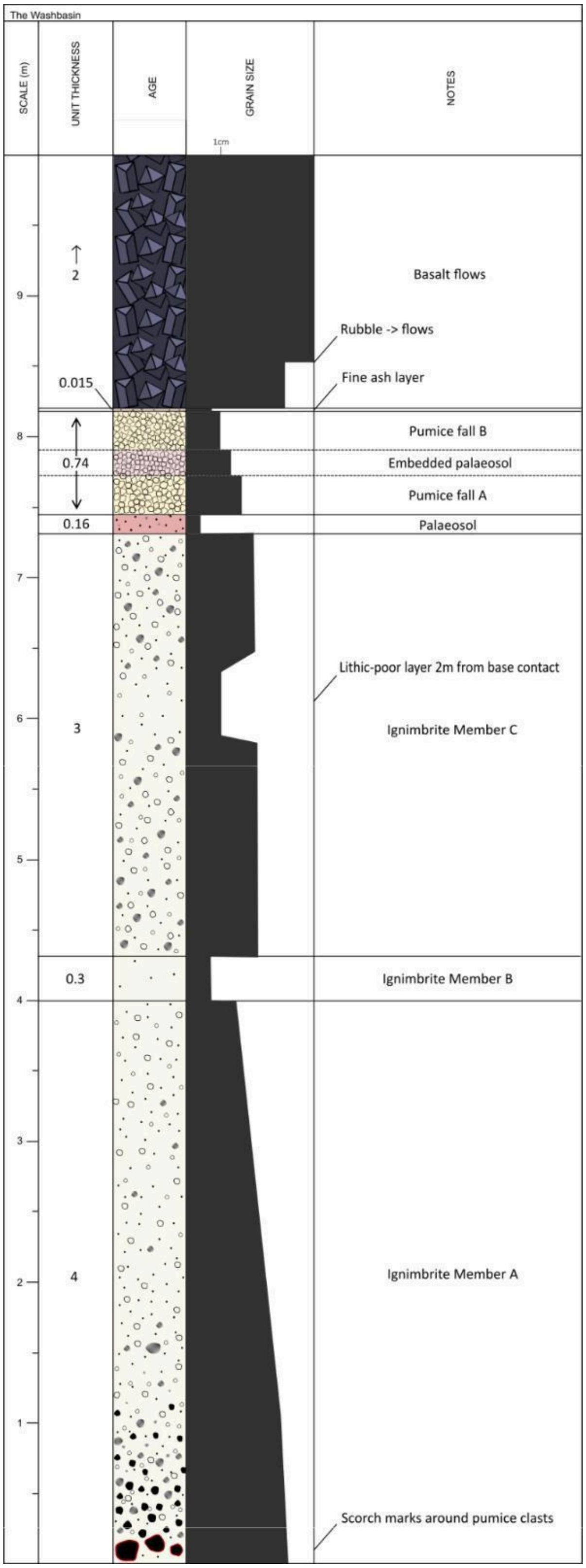

Figure 4: Stratigraphic log of units observed in the "Washbasin" Barranco.

The Washbasin Barranco outcrop in southeast Tenerife exposes a sequence of pyroclastic units (Fig.4) beginning with Ignimbrite Member A, a massive, matrix-supported ignimbrite with coarse, angular pumice and dark, crystal-rich clasts at its base. This is overlain by Ignimbrite Member C, a poorly sorted, cream pumice-rich ignimbrite with weak stratification and scattered dark lithics, resting above the thin, lithic-poor Ignimbrite Member B. Above this lies Pumice Fall Deposit A (PFD-A), a stratified fall layer of medium, angular pumice lapilli sitting over a distinct paleosol. The sequence ends with Pumice Fall Deposit B (PFD-B), a poorly sorted pumice fall with sharp basal and upper contacts and a fine ash layer above.

3.1.3 Porís by the Sea (Alexis' Favourite Outcrop)

The Porís by the Sea outcrop is exposed in the southeast sector of Tenerife in the coordinates N 28° 9' 33.8364 E -16° 26' 6.702 and represents a new pumice fall deposit and ignimbrite followed by the Arico Ignimbrite (Fig. 5). The formation is more than 1m thick, stratified with an inverse to normal grading structure. It is poorly sorted, coarse grain up to 7cm. Pumice is highly vesicular, and rounded. Pumice is often stretched and sheared. The deposit is clast-supported, unconsolidated, and fines-poor. The structure is heterogenous across the dispersal area. A distinct characteristic is the mixing of textures between less evolved and phonolitic magmas.

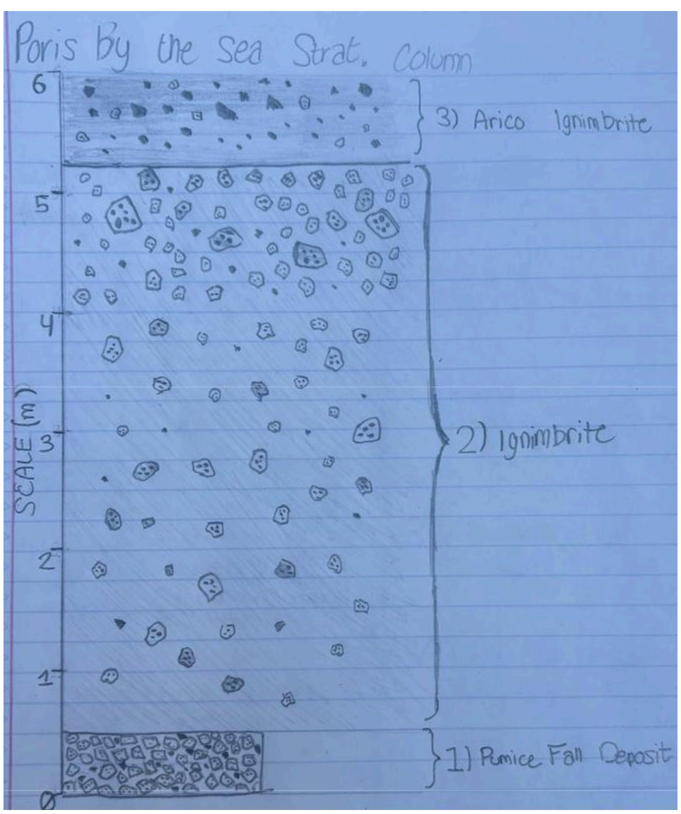

Figure 5: Stratigraphic log of Alexis' favourite outcrop (Porís by the Sea).

3.2 Lower Diego Hernandez (DH) Group, Caldera wall

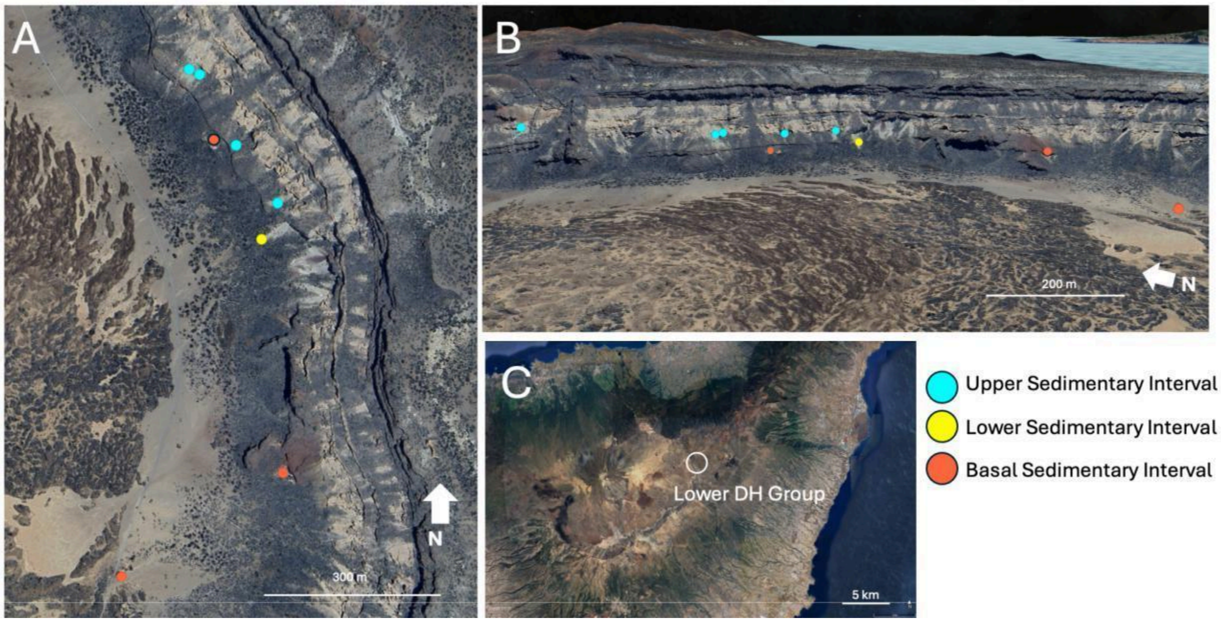

Figure 6: Google Earth images showing views of caldera wall and field locations. (a) Plan view of the DH sector wall, (b) view of the DH sector wall facing ~NE, (c) location of the sector wall within the caldera.

3.2.1 Basal Sedimentary Interval

The first 5 layers of the basal sedimentary interval consist of a bottom scoria layer of 5 meters, then a 1.5 meter PFD, followed by 2.5 meters of lithified ash, then a meter long paleosol layer, and finally a 7.1 meter Scoria layer (Fig. 7). The next six layers consist of a 40 cm paleosol/PFD layer, followed by 40 cm of paleosol. The next layer is another PFD/ paleosol mix that is 0.25 cm thick and clast supported on the bottom while being matrix supported on top. The following layer is a 40 cm clast supported layer, followed by a 50 cm paleosol, and then a
1.5 meter Scoria layer. The next five layers consist of 1.5 meters of lithic rich paleosol, followed by 0.2 meters of a paleosol/PFD mix, followed by 0.4 meters of a clast supported PFD, followed by 0.6 meters of a weathered PFD, and then finally a layer of paleosol. The next layer is an unknown ignimbrite, which contains small layers of lithics with large lenses of lithics wrapping around the rock. The following layer is 0.38 meters of poorly sorted reworked paleosol. Following that is 0.07 meters of grey lithics and a fine red paleosol matrix, 0.53 meters of red paleosol, and finally 2 meters of dark clast supported, angular lava.

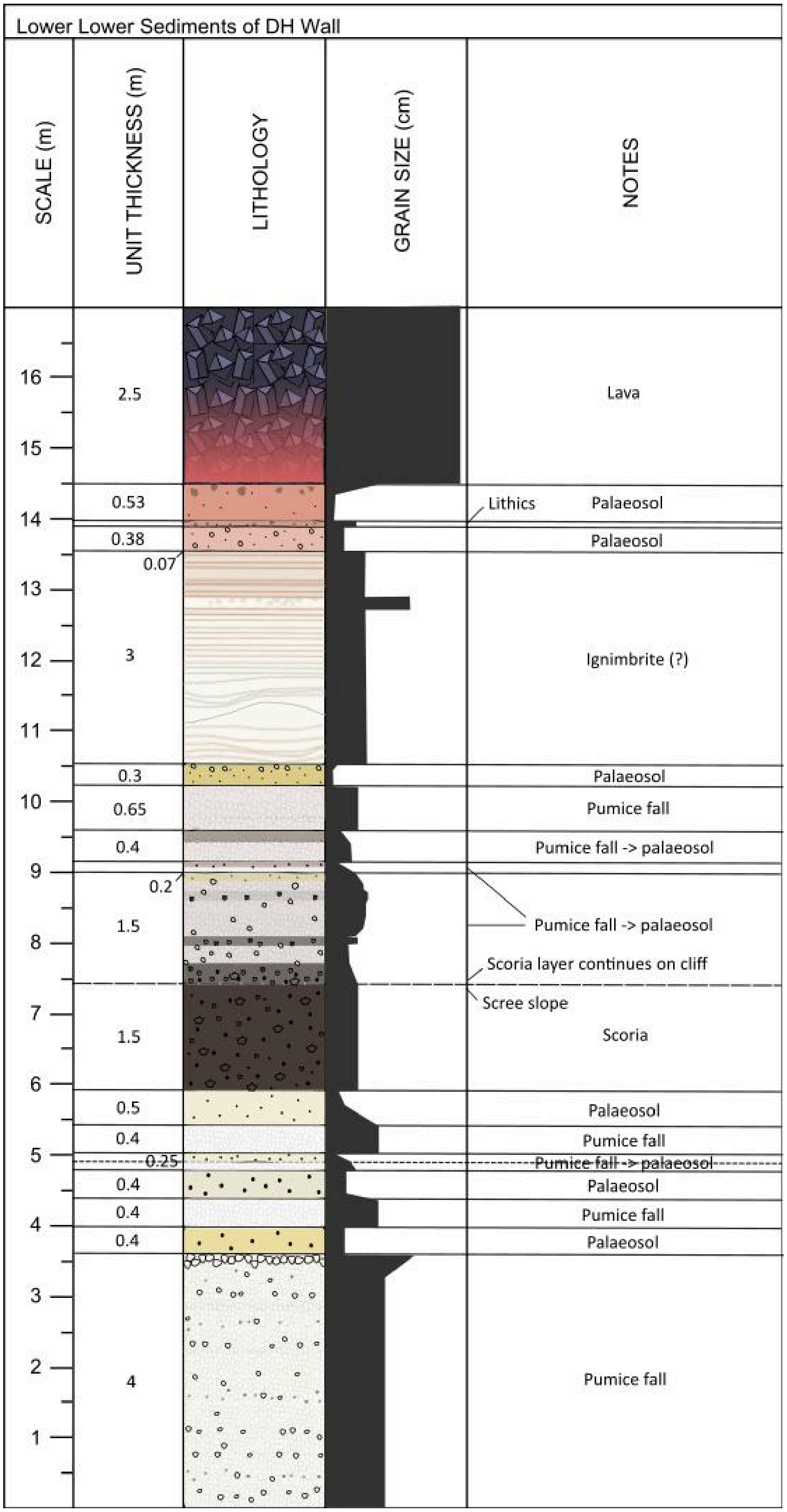
Lower Lower Sediments of DH Wall
SCALE (m)
UNIT THICKNESS (m)
LITHOLOGY
GRAIN SIZE (cm)
NOTES
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
2.5
0.53
0.38
0.07
3
0.3
0.65
0.4
0.2
1.5
1.5
0.5
0.4
0.25
0.4
0.4
0.4
4
Lava
Lithics
Palaeosol
Palaeosol
Ignimbrite (?)
Palaeosol
Pumice fall
Pumice fall -> palaeosol
Pumice fall -> palaeosol
Scoria layer continues on cliff
Scree slope
Scoria
Palaeosol
Pumice fall
Pumice fall -> palaeosol
Palaeosol
Pumice fall
Palaeosol
Pumice fall

Figure 7: Stratigraphic log of basal sediments identified (below known Lower Sedimentary Interval) in caldera wall.

3.2.2 Lower Sedimentary Interval

Previous work by Ethan Hamilton revealed 9 units between the upper sedimentary interval and the basal sedimentary interval with 8 pumice falls and an unknown ignimbrite set between layers of palaeosol (Fig. 8).

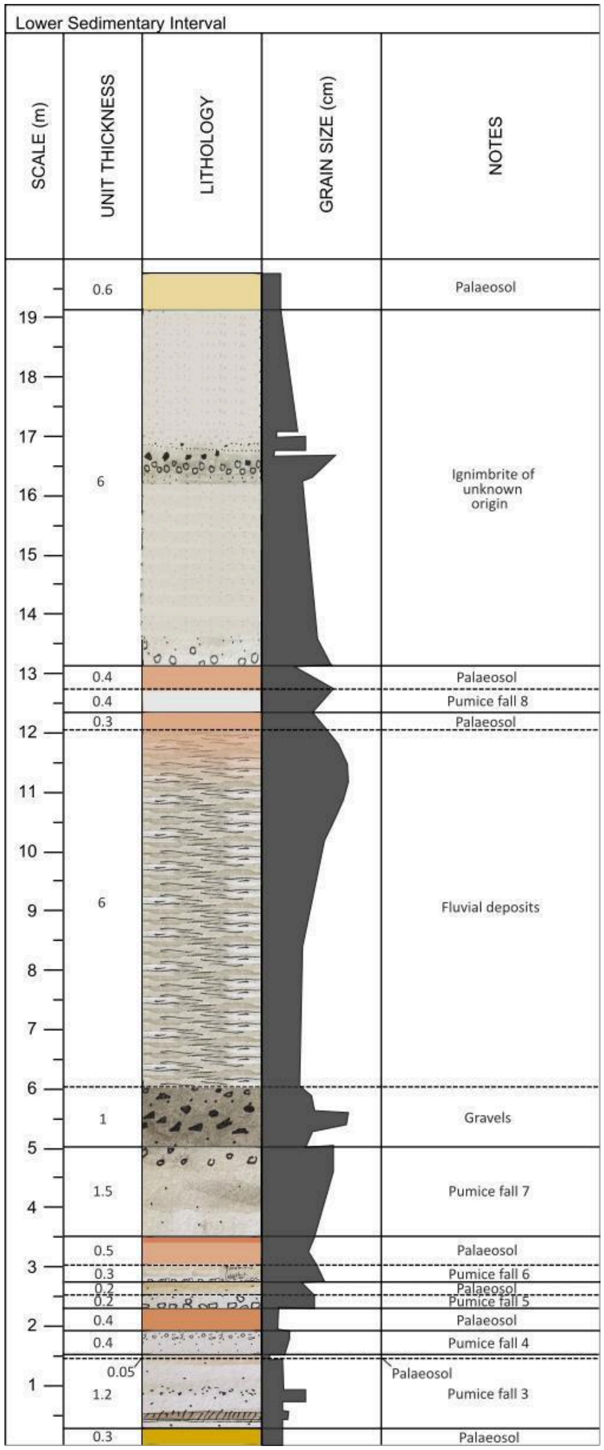

Figure 8: Stratigraphic log of Lower Sedimentary Interval sequence of caldera wall.

3.2.3 Upper Sedimentary Interval

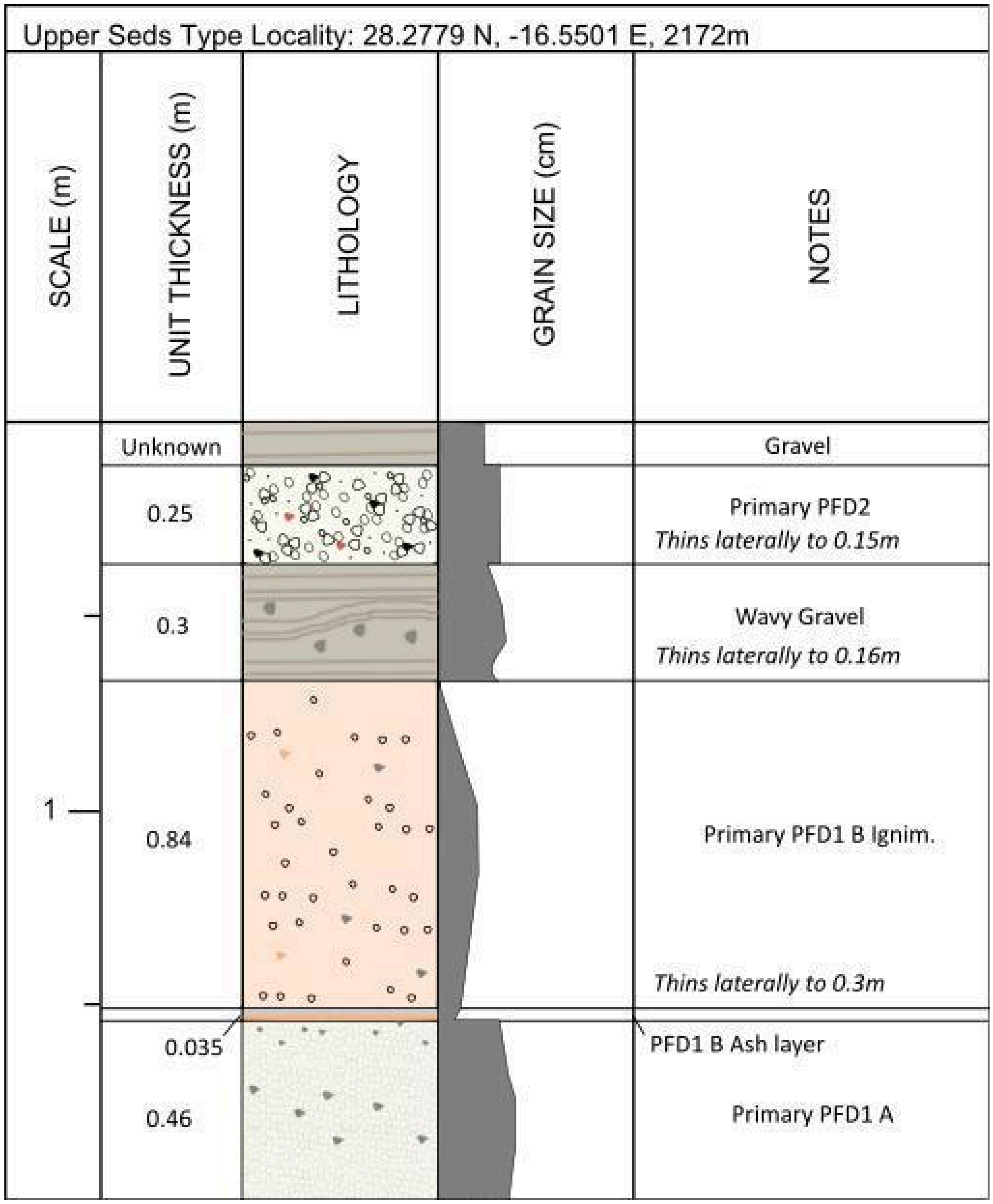

Figure 9: Stratigraphic log of the type locality of the Upper Sedimentary Interval showing maximal thickness of units, noting lateral variation, in caldera wall.

The upper Caldera wall sequence includes several pumice fall and ignimbrite deposits (Fig.9). Primary PFD1 A is a normally graded, moderately sorted fall layer with subangular pumice showing banding, mafic blebs, sanidine and amphibole phenocrysts, and a distinctive presence of red lithics. This member is constantly present along the wall in comparison of the rest of the members. Primary PFD B above it, is a massive, matrix-supportive ignimbrite with orange to cream pumice, and sparse feldspar and biotite, lacking distinctive markers but containing pale orange and black lithics. On top of these, Primary PFD2 is a well-sorted, white pumice fall, sparse amphibole, and low lithic content. The last PFD, which does not correlate with Primary PFD1/PDF2, higher up and offset by faulting, is a poorly sorted, compacted fall deposit enriched in obsidian lithics, with increasing lithic content toward the top and a distinct ash layer above.

Below PFD1 is a series of gravels of highly variable thickness (10s cm to 8.5m diagonal thickness) intercalated with numerous discontinuous, matrix supported and compositionally heterogeneous deposits, with rounded to sub-angular pumice up to 20cm thick.

3.2.4 Structure of the DH Sector Wall

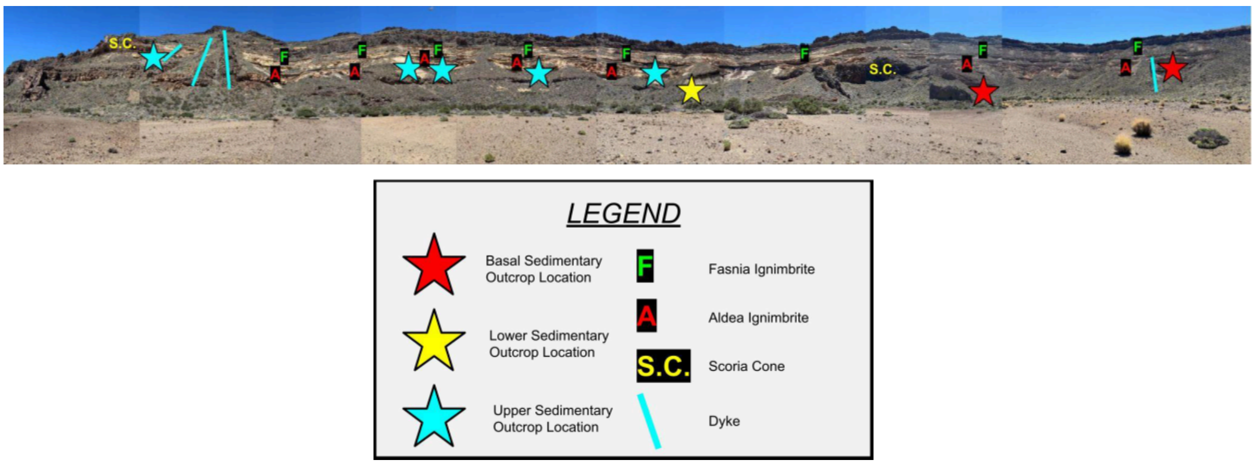

Figure 10: Panorama of Caldera wall with mapped outcrop locations, ignimbrites, scoria cones, and dykes.

The lower section of the Diego Hernandez formation is capped by a series of lava flows, one of which is sourced from an eroded scoria cone on the left edge of the wall (Figure 10). Beneath the lava is the Fasnia ignimbrite formation, which is mostly continuous along the entire segment. A thin scoria deposit marks the border between the Fasnia and Aldea ignimbrites. The Aldea ignimbrite is fairly continuous throughout the wall, but is interrupted by dykes, scoria cones, and more weathered portions. Beneath the Aldea ignimbrite is three separate layers of sedimentary deposits consisting of PFDs, paleosols, and smaller ignimbrites.The Basal layer is only located to the south of the lower scoria cone and is at the same level as the Lower layer, indicating some event took place to offset, erode, or uplift these deposits.

3.3 Upper Diego Hernandez

3.3.1 Jam sandwich outcrop / La Tarta

The La Tarta sequence, exposed in the central Teide region, consists of a massive ignimbrite overlain by stratified pumice fall deposits. The ignimbrite is clast-supported, poorly to moderately sorted, with angular to sub-angular, strongly vesicular pumice showing sheared textures and interlocking clasts, and angular lithics concentrated at the base. Above it lies a pumice fall deposit displaying inverse to normal grading, banded pumice, stretched vesicles, circular vesicles, and lithics in shades of black, red, and grey. Underlying layers include an ash bed with accretionary lapilli, a lithic-rich lapilli layer, and a lower pumice fall bed with sanidine-bearing, obsidian-rich banded pumice.

3.3.2 Dorsal ridge/Volcán de Fasnia (the LaGro outcrop)

Near Volcán de Fasnia, a northeast-dipping outcrop reveals four pyroclastic sequences composed of pumice fall, ash, and ignimbrites, separated by scoria layers (Fig. 11). The lowermost sequence begins with a homogeneous, clast-supported, lithic-poor pumice fall deposit containing angular to subangular pumice with stretched vesicles and sparse dark grey lithics. This is overlain by a white ash layer rich in accretionary lapilli, which transitions into a heterogeneous Pyroclastic density current (PDC) deposit with interbedded ash-rich and lapilli-rich lenses, concentric lapilli up to 2.5 cm, and a moderate increase in lithics toward the top. The sequence is capped by a reddish paleosol with reworked pumice and overlain by a scoria fall.

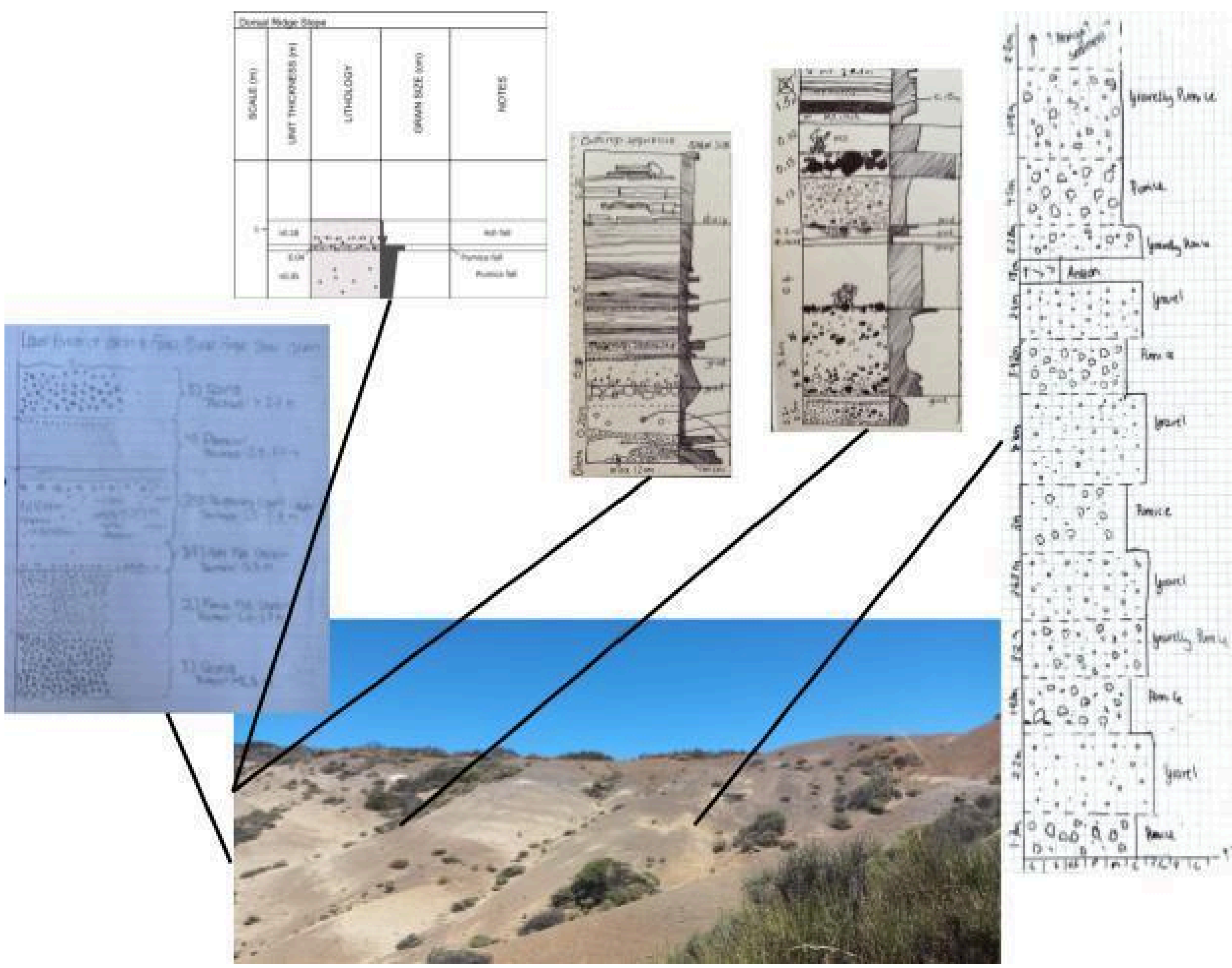

Figure 11: Stratigraphic logs compiled with field locations in the Dorsal Ridge locality.

The lower PFD is a coarse, poorly sorted, clast-supported unit with large (up to 60 mm) subangular white pumice displaying round and spiderweb-like vesicles, rare crystals, and occasional dark patches; it becomes more consolidated downward and contains angular lithics, capped sharply by an ash layer. The upper PFD, stratified and finer-grained, contains subangular white pumice (2–20 mm), is moderately sorted, and distinct for its ~15% lithic content of grey, black, and light red fragments, although lateral visibility is limited due to slope conditions. PFD-4, situated below scoria-rich layers, is a well-sorted, stratified unit with normal grading, featuring stretched pumice, a base enriched in accretionary lapilli, obsidian, and small red lithics. Lastly, PFD-5 is a thick, multi-pulse sequence of pumice and gravel interbeds, with moderate to poor sorting, vesicular to stretched pumice, obsidian and oxidized red lithics, showing vertical color changes and lithic variation, and terminating at an unconformity.

4.Discussion

4.1 Guajara Group

Stratigraphy examined in Barranco Tamadaya, the Washbasin Barranco and Porís by the Sea locations is below the Arico ignimbrite (Fig. 3,4,5), and so are part of the Guajara Group. Possible identification of ignimbrites described and/or discussion of their position in the Guajara stratigraphy, and possible interpretations of eruptive processes are discussed below.

4.1.1 Barranco Tamadaya

The Barranco Tamadaya ignimbrite is characterized by poorly sorted lithic blocks and bombs near the bottom of the ignimbrite, lapilli and pumice in the middle, and chunks of grey pumice. The PFD sat atop the ignimbrite contains lithics with red powder. Despite these characteristics, it remains unclear whether the ignimbrite correlates to a previously discovered deposit. Further testing and research could be conducted to reveal details on the history of the Barranco Tamandaya deposit.

4.1.2 Washbasin Barranco

The ignimbrite exposed at the Washbasin Barranco site is interpreted as part of the Guajara Formation based on its stratigraphic position beneath the Arico Member and lithological characteristics. It includes a series of pyroclastic flow and fallout deposits pre-dating the Arico Member. The Washbasin has a massive structure, poor sorting, angular to sub-rounded coarse pumice with low-to-moderate sphericity, and abundance of crystal-rich, dark basal clasts which are all features consistent with early explosive phases of the Guajara eruptive cycle (Dávila Harris et al., 2009, 2023). Although not directly correlated with a specific member, the Washbasin Ignimbrite A likely represents a previously undocumented lower ignimbrite of the Guajara Formation, part of the pyroclastic record preserved in the southeast sector of Tenerife.

4.1.3 Porís by the Sea (Alexis' Favourite Outcrop)

A key characteristic of both the ignimbrite at Porís by the Sea and the Eras Ignimbrite is the mixing of magma textures within the structure. The Eras member contains evidence of phonolitic white pumice clasts as well as a fall deposit beneath the ignimbrite, which in indicative of a more evolved phonolitic magma, whereas the upper section of the ignimbrite contains black banded pumices (Middleton, 2006). Similarly, we noted that the outcrop at Porís by the Sea contained the distinct characteristic of less evolved black clasts and phonolitic magma textures mixed together. Both ignimbrites also contain black and white clasts of banded pumice. Based on these similarities, we have come to the conclusion that the ignimbrite near Porís and the Eras Ignimbrite are the same.

4.2 Lower Diego Hernandez (DH Sector Wall, Caldera)

Sedimentary intervals of the DH sector wall investigated are below what is suspected to be the Aldea formation (Fig. 10). Continuity of sedimentary intervals across the DH sector wall and implications for understanding of the eruptive history during this time are discussed below.

4.2.1 Basal Sedimentary Interval

Sediments identified in this sector have been faulted upwards and are now at the same elevation as the LSI units at (Fig. 10, see 4.2.4 for discussion of structure). As such these sediments are older than the LSI and have been termed the Basal Sedimentary Interval. The age of these units likely extend into the hiatus in volcanic activity suggested to occur between the DH and Guajara groups (Cas et al. 2022 and references therein). This sedimentary package includes eight previously unidentified pumice fall deposits, and one flow deposit which may be an ignimbrite or surge deposit (Fig. 7), thus extending the explosive eruptive history of the DH cycle back in time. This presents a challenge for understanding the eruptive history of Las Cañadas more fully, as any record of older PFDs within the caldera is likely buried by younger caldera fill material.

4.2.2 Lower Sedimentary Interval

The units of the Lower Sedimentary Interval were found to be untraceable across the DH sector wall, potentially due to faulting (see 4.2.4 for further discussion). Tracing laterally from the LSI led to finding the Basal Sedimentary Interval but no further LSI outcrops.

4.2.3 Upper Sedimentary Interval

The deposits within the lower sections of scree slopes of the USI between the gravels and palaeosols are of unknown origin. Deposition via pyroclastic surges or by lahars are suggested since these deposits are heterogeneous in composition, matrix supported, contain rounded pumice clasts, and are laterally discontinuous (e.g., Sparks et al., 1973). This is inferred to be due to the high erosive power and fast deposition of a wide range of materials in pyroclastic or lahar events. The tendency of these deposits to pinch out over short distances (<10m in one case; ref results) will likely render these useless for correlating stratigraphy but are evidence of high-energy explosive activity beyond current knowledge of eruption events.

Within the upper section of scree slopes within the USI, two primary PFDs (PFD1 and PFD2) and an ignimbrite were identified, with PFD1 associated with and stratigraphically below the ignimbrite (Fig. 9). As such, the ignimbrite and PFD 1 are interpreted to have been deposited during one eruption. Lateral discontinuity of the ignimbrite could be due to infilling by the pyroclastic density current of palaeotopography, but this is uncertain. As PFD2 is only observed in one location due to vegetation and scree cover, its exact stratigraphic position is unclear.

Neither PFD1 or PFD2, or the ignimbrite appear to correlate to descriptions of previously identified eruptive deposits noted below the Aldea formation by Edgar et al. (2007; Roque and Fortaleza members).

4.2.4 Structure of the Diego Hernandez Sector Wall

The Las Cañadas Caldera wall exposures record the complex volcanic and sedimentological histories following historic volcanic eruptions (Cas et al., 2022, see Geologic Context). This volcaniclastic stratigraphy is characterized by laterally continuous to steeply tilted fault blocks, consisting of ignimbrites, pyroclastic fallout deposits, scoria and lava flows. These are interbedded by reddish coloured palaeosols and screes. In several locations throughout the wall, there are offset and disrupted stratigraphy (Fig. 10). Though at this current point in time, we cannot ascertain for certain the cause of the disruption in stratigraphy. We propose two models for how these structures likely occurred. Firstly is the caldera subsidence model (Figure

12: Left Image), that ongoing sedimentological subsidence events led to the removal or sliding of less competent strata, which could cause downthrowing of sections of the caldera wall. A second proposed model (Figure 12: Right Image), that previously deposited pyroclastic material along the Aldea member was later slightly uplifted by intrusions. A history of magmatic intrusions post-Aldea deposition is evidenced by the multiple dykes which cross cut the caldera wall stratigraphy (Fig. 10, 12). Though it is important to note, both of these phenomena could have been locally occurring through the caldera wall growth history.

Figure 12 : (Left Image) Model 1: The Caldera subsidence model as a proposed explanation for disrupted lateral stratigraphy. Here the removal of less competent stratigraphy via subsidence or landslides led to offsetting of stratigraphy. (Right Image) Model 2: The Dyke intrusion model, which proposes that the offset in pre-deposited stratigraphy was caused by a late occurring magmatic dyke intrusion which upheaved the hangingwall stratigraphy.

4.3 Upper Diego Hernandez

4.3.1 Jam Sandwich outcrop/La Tarta

The exposed stratigraphy at La Tarta shares several features with Unit H of the Upper Fasnia Sequence described by Edgar et al. (2017), although the correlation remains tentative. The deposit shows inverse grading followed by normal grading, angular to sub-rounded pumice lapilli with circular vesicles, and a fines-poor, clast-supported texture—traits typical of pumice fallout in Unit H. The presence of banded pumice, alkali feldspars, and black, red, and grey lithics also supports a possible match with evolved subunits in the sequence. A compact ash layer with accretionary lapilli beneath the fallout is especially notable and might relate to surge or co-ignimbrite deposits, similar to those found in Unit I or the Ravelo ignimbrite. While these comparisons are promising, further geochemical analysis would help confirm the link.

4.3.2 Dorsal Ridge, near Volcán de Fasnia (the LaGro outcrop)

The units described at the vicinities of Volcán de Fasnia (Montaña de Fasnia), on the northeastern flank of the Las Cañadas volcano, overlap the units described at the Las Cañadas Caldera wall section (with dips towards NE; Fig. 11). The lowermost unit comprises a sequence of a white pumice fall deposit and an ignimbrite packed in between black scoria deposits. The subtle stratification and the striking intercalation of accretionary lapilli-bearing and ash lenses of the PDC deposit allows its correlation with the Porís Formation (c.f. Brown et al., 2003), with the mentioned sequence corresponding to its first members (1-4). The thickness of the unit (min. 5 m) and the lack of paleosoils or erosive surfaces between the deposits suggest a large sustained eruptive event, while the increase of lithic fragments towards the top of the sequence,

with bigger, more angular and diverse clasts, including phaneritic rock, suggest a caldera-related paroxysmal phase. The higher content of coarse-grained (up to 2.5 cm) accretionary lapilli suggests the presence of external water.
The following unit encompasses two different sequences of pumice fall and ashfall deposits wrapped by dark coloured scoria deposits. Although their structural and textural variability (e.g. massive to stratified, locally compacted, variations in grain size and shape) makes it difficult to accurately correlate them with previous defined units, their stratigraphic position and some characteristics such as sparse accretionary lapilli and pumice clasts with composition variation suggest their correlation with the La Caleta Formation. These deposits may have originated from Plinian events. As such, the only known stratigraphy missing from this section is the Arafo formation which occurs between the Porís and La Caleta formations (Brown et al. 2003, Edgar et al. 2007).

Finally, the uppermost unit comprises a thick (> 13 m) sequence of lithic-rich poorly sorted pumice fall deposits and ignimbrites. Its stratigraphic position, sorting and remarkable high lithic contents suggests a correlation with the Abrigo Formation, originated by caldera-forming Plinian events. It is important to note, that the pristine outcrop is correlated to the Abrigo Member, the stratigraphy to the west is probably also Abrigo, but has undergone more severe post emplacement sedimentary reworking.

The presence of scoria deposits intercalated with the phonolitic sequences interpreted as belonging to the youngest units of Diego Hernandez Group indicate periods of quiescence in the Las Cañadas Caldera system, when eruptions are restricted to extra-caldera, local smaller events resulting in monogenetic cones.

5. Conclusions and Recommendations

The Ignimbrites described at Barranco Tamadaya and the Washbasin Barranco have not been correlated with known ignimbrites, but are strongly suspected to form part of the Guajara Group due to their position below the Arico ignimbrite. The pumice fall deposit and ignimbrite below the Arico ignimbrite at the Porís by the Sea location are suspected to be part of the Eras formation due to similarities in pumice vesicularity and composition. The volcanic-sedimentary packages identified in the DH sector wall of the Caldera are not identified elsewhere on the island and represent a more extensive and older history of eruptions within the DH Group than previously recognised. The fall deposit and ignimbrite described at the Jam Sandwich exposure have been correlated with the La Tarta exposure and identified as part of the Fasnia Formation. The lower fall deposits and ignimbrite at the Volcán de Fasnia/LaGro location have been identified as the Porís and La Caleta Formations. The multiple upper pumice fall deposits have not been correlated or identified. The uppermost ignimbrite at the Volcán de Fasnia/LaGro location may be the Abrigo ignimbrite.

Future work should include further detailed investigation of the ignimbrites found at Barranco Tamadaya and the washbasin barranco to identify fingerprint characteristics to more confidently determine whether or not these are correlatable with known ignimbrites. If it is determined that these are different ignimbrites than those previously identified, further reconnaissance work should be conducted to find these ignimbrites elsewhere on the island to determine their spatial extent. Within the caldera wall, more detailed description and interpretation of units identified will provide greater detail into the eruptive history, including eruption styles, of the Las Cañadas volcano. Further effort to assess the structural history of the caldera wall will provide more insight into the collapse mechanisms that formed the caldera.

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Appendix - Full Descriptions of Ignimbrites and Fall Deposits

Guajara Group

Barranco Tamadaya

The Barranco Tamadaya formation is exposed near the Area Recreativa el Contador and is stratigraphically below the Arico formation.

At the type locality, the first unit is 2 meters thick and moderately sorted, with angular and subangular pumice clasts that are smaller and less vesicular in the dark band of pumice. Thickness of the formation varies from 1.5 to 2 meters. Matrix is present with cream colored, fine ash. The formation is clast supported with a distinct characteristic in the field being that the top 0.5 meters contain darker pumice clasts. This formation is the first visible on the bottom of the sequence and is capped by a layer of paleosol before the next significant layer deposited.

The second layer is an ignimbrite that is 2 meters thick and well graded, with poorly sorted blocks and bombs at the bottom, poorly sorted pebbles, lapilli, and pumice in the middle, and then chunks of grey pumice at the top. The pumice is angular to subrounded and moderately vesicular with a matrix supported structure. The clast percentage is 60% with a distinct characteristic in the field being the lapilli present in the middle of the ignimbrite and the pumice clasts near the top. At the type locality, the ignimbrite has a lower contact with paleosol and an upper contact with ash. There is 0.84 meters of ash and paleosol with some pumice clasts before the first major pumice fall deposit (PFD).

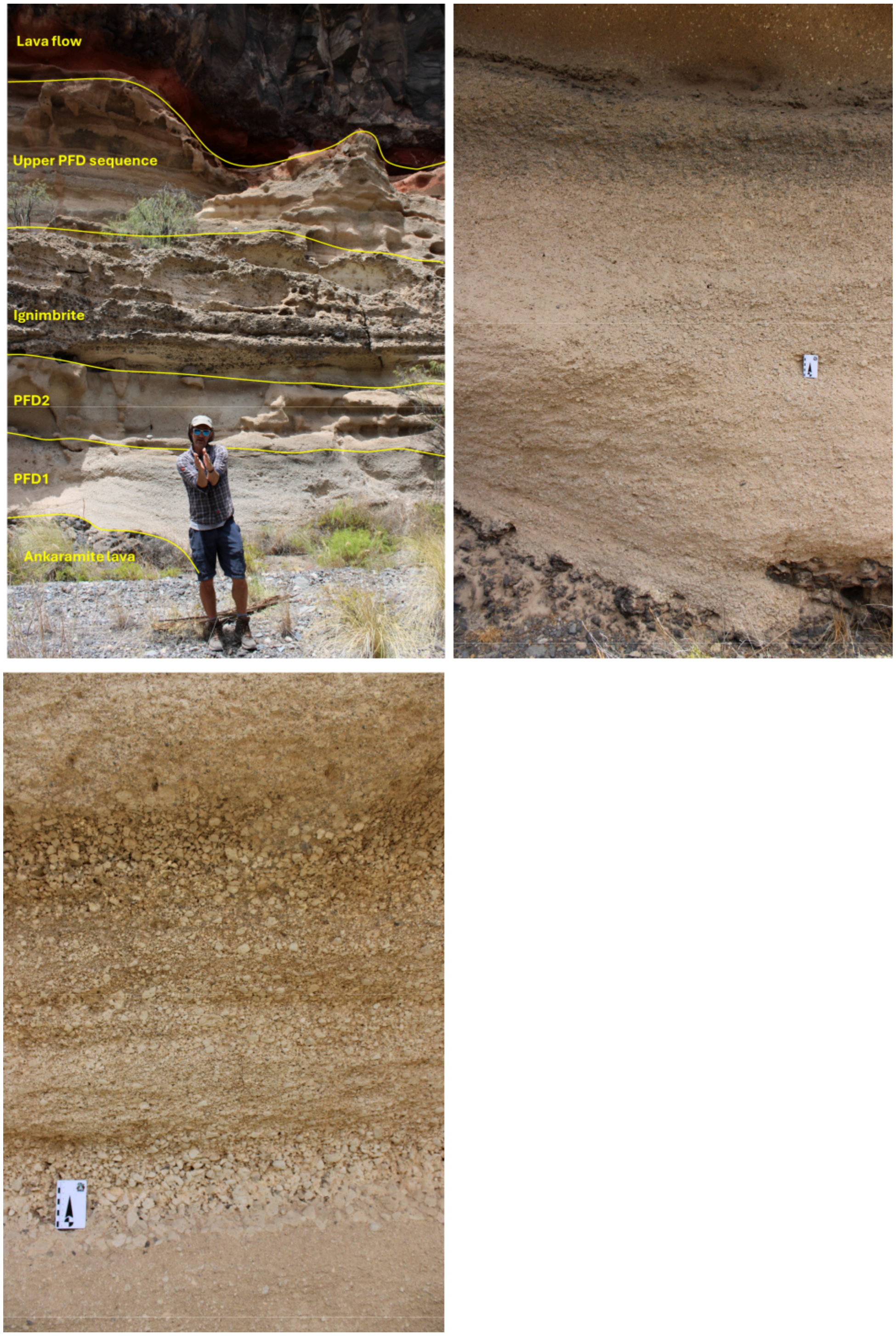
The first layer in the PFD formation is 0.8 meters thick with angular, well sorted pumice. The second layer contains angular, poorly sorted clasts, as does the third layer. These layers are supported by a matrix structure up until the third layer, which is clast supported. The pumice in the first and third layers are reworked, while the middle layer remains unclear on pumice morphology. The deposit has no distinct characteristics. This formation has a lower contact with paleosol and an upper contact with a 0.072 meter pumice fall that is moderately sorted and clast supported.

The next major pumice fall deposit is 0.51 meters thick, moderately sorted with angular pumice clasts that have small vesicles and contain phenocrysts and sanidines. The formation is matrix supported near the top, however it transitions to be more poorly sorted and clast supported on the bottom of the structure. A distinct characteristic is that it is set apart from the reddish layer below it due to being less crumbly. At the type locality, this pumice fall has a gradational lower contact with the reddish layer as it transitions to be more yellow and a continuous upper contact with soil.

The next pumice fall is 0.7 meters up, with the deposit being 0.18 meters thick, laterally continuous, and poorly sorted. The pumice is cream colored and angular with less vesicles. The formation is matrix supported and poorly consolidated, with a distinct characteristic being the presence of “bleeding lithics”, which were dark pieces of basalt surrounded by a red halo set in the pumice. The pumice fall has a short gradation into the lower contact and a gradational upper contact.

After a 0.03 meter ash layer, the next pumice fall deposit is a 0.05 meter thick, moderately sorted, laterally continuous layer with angular cream and grey colored banded pumice. The formation is clast supported and distinct due to the dark banded pumice deposited throughout. The formation zig-zags into the lower contact and a planar long gradation into the upper contact, which is 0.43 meters of soil.

The final significant layer before the basalt flow is a pumice fall that is 0.56 meters thick, poorly sorted, and has varying thickness laterally. The pumice is grey and dark colored and the structure of the formation itself is clast supported. A distinct characteristic in the field is the gradation as there is a bed around 4cm above the short gradation from the bottom contact where the pumice clasts are significantly smaller, as well as the wavy top contact with the red layer below the basalt.



Upper left: General stratigraphy of the type locality. Upper right: PFD1 - massive to stratified deposit, with colour variation upwards, indicating compositional change throughout the deposit. Lower left: PFD2 - Stratified (normal-inverse) pumice fall deposit.

Washbasin Barranco

Ignimbrite Member A

The Washbasin Barranco formation is exposed in the south east area with the coordinates 28°09'50.4"N 16°27'35.9"W and, is a new pumice fall deposit, named after the Wasbasin Tajo found a few meters before. At the type locality, the formation is 4 m thick, massive, ungraded, very poorly sorted, coarse lapilli to block sized, with angular to sub-rounded, elongate/tubular, low-to-moderate sphericity pumice. The formation is matrix supported, consolidated, and fines-poor. The structure is heterogeneous upwards the dispersal area. A distinct characteristic is the abundance of very dark, crystal-rich pumice at the base with scorch marks around pumice clasts. At the type locality, the Ignimbrite Member A formation does not have an exposed lower contact, but a sharp upper contact with Ignimbrite Member B. The formation has not been documented at the type section and is laterally assumed continuous.

Ignimbrite Member C with B noted

The Washbasin Barranco Ignimbrite Member C is on top of the thin Ignimbrite Member B (0.3 m, pumice-and litic-poor), and it is below the paleosol/pumice fall deposit. Member C is 3m thick, massive to weakly stratified, ungraded, poorly sorted, coarse lapilli pumice that is angular to sub-rounded, yellow/cream with dark/grey lithic clasts, moderate sphericity. Matrix supported, consolidated, and fines-poor to moderate. The structure is slightly heterogeneous (a lithic-poor layer ~2m above the base). At the type locality, the Ignimbrite Member C formation has a sharp lower contact with Member B and a sharp upper contact with a paleosol layer (0.16 m) then Pumice Fall A. The formation does not have a thickness variation recorded, and is laterally presumed continuous at outcrop scale.

Pumice Fall Deposit A (PFD-A)

The PFD-A of the Washbasin Barranco is 42 cm thin above the 0.16 paleosol, it is stratified, normally ungraded to very slightly graded, medium sorted, medium lapilli, angular pumice. It is clast supported, unconsolidated, fines-poor. The structure is homogeneous across the dispersal area. A distinct characteristic is the light pink palaeosol directly beneath. At the type locality, the PFD-A formation has a gradational upper contact with a paleosol layer (0.40). The formation is laterally continuous at outcrop scale.

Pumice Fall Deposit B (PFD-B)

The whole type section is found below the Arico ignimbrite. The type locality, the unit is 0.74 m thick, stratified, ungraded, poorly sorted, medium lapilli (4-13 mm), angular pumice, equant to slightly elongate with moderate sphericity. It is clast supported, unconsolidated, and fines-poor. The structure is homogeneous across the dispersal area. A distinct characteristic is the very sharp basal and upper contacts and the overlying 0.015 m fine ash layer that separates the lava flow. The unit contains a sharp lower contact with the paleosol layer. The formation appears to be continuous at outcrop scale.

Lower Diego Hernández

Basal Sedimentary Interval

The Montana de Fasnia formation is exposed in the Las Cañadas Caldera and is below the Abrigo formation and above the Arico formation. The layers dip 20˚ toward N65E.

The first layer of the Montana de Fasnia is a 5 meter thick Scoria layer that is clast supported with angular black clasts. Following the Scoria layer is a PFD with a thickness of 1.0 to 1.5 meters. It is clast supported white angular and subangular white pumice and is homogenous throughout. Layer 3 has a thickness of 2.0 to 2.5 meters with the bottom containing lithified ash and the top containing more fine grained ash with lithics. The layer is matrix supported with rounded accretionary lapilli more near the top. Layer 4 is around a meter of paleosol. Layer 5 is a scoria layer 7.1 meters thick. The layer is clast supported with angular black clasts.

A 40 cm paleosol layer containing white pumice clasts separates layer 5 from the next PFD with a 5 cm gradation into the next 40 cm paleosol. Following the paleosol is a 0.25 cm PFD/Paleosol mix with finer clasts supported by matrix near the top, but clast supported near the bottom. Following a clear boundary, the next layer is a 40 cm clast supported layer with a sharp gradation on the bottom and a semi sharp contact with the 50 cm paleosol above it. Following the paleosol layer is a matrix supported scoria layer that continues upwards from 1.5 meters into paleosol and then into a cliff sequence.

The paleosol is characterised by an obsidian lithic rich top with 3-5 mm pumice clasts. There is a sharp contact before the next layer, which is 20 centimeters and clast supported on the bottom and a lithic poor layer of paleosol. The upper contact is sharp as this layer contains well sorted, coarse clasts. Some significant characteristics are that the pumice contains pyroxene and the lithics are grey and orange apholitic. There is a 5 cm gradation into paleosol, which makes up the first 15 cm of the next layer, which is 65 cm overall. The layer is heavily weathered and compact with less gradation at the contacts. It is clast supported and homogeneous throughout. The layer grades into a paleosol with reworked pumice, which is reddish, matrix supported, and very fine grained.

The next layer is an unknown ignimbrite, which contains small layers of lithics with large lenses of lithics wrapping around the rock. The ignimbrite has a lateral erosion surface with angular clasts and 6 subrounded boulders. The lithic concentration gradually increases near the bottom of the ignimbrite. The following layer is 0.38 meters of poorly sorted reworked paleosol. Following that is 0.07 meters of grey lithics and a fine red paleosol matrix, 0.53 meters of red paleosol, and finally 2 meters of dark clast supported, angular lava.

Upper Sedimentary Interval

Primary PFD1 A (pumice fall deposit)

The Primary PDF1 A formation is exposed at various locations throughout the Caldera wall and is a previous identified pumice fall deposit. At the type locality, the formation is 0.46m thick, massive, normally graded, moderately sorted, fine to medium grained, with subangular pumice. The pumice is 1–20mm in diameter, with white and light grey banding, mafic blebs, sparsely porphyritic with sanidine, biotite, and amphibole phenocrysts, and has spherical tabular vesicles. The formation is clast supported, consolidated, and homogeneous across the dispersal area. The deposit has a distinct characteristic of a significant presence of red lithics. At the type locality, the formation has a shortly graded lower contact with a paleosol and a sharp upper contact with an ash layer. This ash layer is typically 0.03–0.1m, with an occasionally 1cm orange band along the bottom that grades into white ash. If the ash layer is not present at other localities, then the upper contact is with a gravel or a paleosol layer. The formation exhibits thickness variation of 0.32–0.65m and is laterally continuous. The formation has a lithic content (5–10%) of 1-20mm, with red, brown, grey, and black colors. The top 10cm of formation has a sudden increase in lithic concentration (+5–10%), as well as a decrease in lithic size (1–10mm).

Primary PFD1 B (ignimbrite)

This formation is exposed below Primary PFD2 and has been previously identified as an ignimbrite. It only appears in conjunction with Primary PFD1 A below it. At the type locality, the formation is 0.84–0.30m thick, massive, ungraded, very poorly sorted, containing subangular to rounded pumice. The pumice is 1–40mm in diameter, 20mm on average, orange and cream, sometimes banded, adheres (black) mafic blebs, is sparsely porphyritic with sanadines and biotite phenocrysts, and has rounded and elongated tubular vesicles. The formation has a 5–7% lithic content of 1–15mm in diameter (occasionally up to 16cm), which are pale orange and black colored. The formation is matrix supported and well consolidated. The deposit has no distinct characteristics. The formation has a wavy and sharp lower contact with Primary PFD1 B (ash layer), and a lower contact with an unconsolidated gravel bed. The formation exhibits thickness variations of 0.06–0.84m, and is laterally discontinuous—it is unknown if this is due to paleotopography or erosion.

Primary PFD2

The Primary PFD2 formation is exposed in the Upper Sedimentary Interval of the Lower Diego Hernandez Group in the Caldera wall, and is a newly identified pumice fall deposit, named after its position above the previously identified Primary PFD1. At the type locality, the formation has a strong lateral variation of 0.15–0.25m thick, and is massive, ungraded, well sorted, containing sub-angular pumice. The pumice is 2–12mm in diameter, white, has mafic blebs, is sparsely porphyritic with 1mm amphibole phenocrysts, and has rounded vesicles (5%). The formation has a 3% lithic content of 3-40mm in diameter, mostly dark and red colored. The formation is clast-supported, unconsolidated, and fines-poor. The formation has no distinct characteristics. The formation has a very wavy lower contact with a gravel layer underneath and an unknown upper contact. It is unknown if the formation exhibits thickness variations or is laterally (dis)continuous due to vegetation and scree.

NOT Primary PFD1

The NOT Primary PFD1 formation is exposed in the Upper Sedimentary Interval of the Lower Diego Hernandez Caldera wall, past the dyke complex in the northern direction (see: Structure of the DH sector wall) and on the footwall of a normal fault. It is a new pumice fall deposit. It's named after the fact that it isn't the Primary PFD1 that is traceable laterally on the other side of the fault on the hanging wall. Based on faulting and altitude, it is likely placed higher and later in the DH stratigraphy. At the type locality, the formation is 0.30m thick, massif, graded (lithics increase toward the top, most abundant in top 5cm), poorly sorted, with undistinguishably shaped pumice (due to compaction). The pumice is 7–10mm in diameter. The formation has a high lithic content (10–20%) of 1–5mm in diameter, with 80% of all lithics being obsidian, and 10% being red colored. The formation is clast supported, very well consolidated, and fines-rich (20% matrix). A distinct characteristic is the high degree of obsidian lithics. At the type locality, the formation has a lower contact with potentially paleosol and a sharp upper contact with an ash layer (dark, fine matrix, 3mm pumice clasts). Above the ash layer there is also a 5m thick ignimbrite that is laterally continuous until the dyke complex.

Upper Diego Hernández

Jam Sandwich

The La Tarta ignimbrite is exposed in the central Teide region and is part of the mid-slope pyroclastic succession, named after the La Tarta road outcrop. The type section is found at coordinates 28˚20'1.2'' N, 16˚29'22.8'' W.

At the type locality, the ignimbrite unit is ~1.5–2.2m thick, massive, with a sharp lower contact and a gradational upper contact into PFD deposits. The ignimbrite shows weak grading, poorly to moderately sorted textures, and contains angular to sub-angular pumice lapilli (1 mm – 7.5 cm). Pumice is sheared and strongly vesicular with interlocked clasts at the base. The deposit is clast-supported, unconsolidated, and fines-poor. The structure is heterogeneous across the dispersal area. A distinct characteristic in the field is the blocky, with coarse pumice and angular lithics, with lithics concentrated at the base and up to 2.5 cm in size.

The ignimbrite has a sharp basal contact with palaeosols and a gradational upper contact with overlying PFD deposits. It is laterally continuous with some thickness variations depending on slope exposure.

PFD la Tarta

At the type locality of La Tarta, the formation is 2.2m thick, stratified, with a sharp basal contact and a gradational upper contact into a soil horizon. The deposit shows an inverse grading in the lower third, followed by normal grading upward. Sorting ranges from moderately poor to poor. It is coarse grained, with angular to sub-rounded pumice lapilli, showing moderately to strongly vesicular textures with stretched vesicles and occasional interlocking clasts. The deposit is clast-supported, unconsolidated, and fines-poor. Key characteristics;

circular vesicles, presence of alkali feldspars, black, red and grey lithics, and banded pumice lapilli.
Below it is a 14cm ash bed layer, compact, with accretionary ash lapilli. There's a sharp contact below this PFD with a 3cm bed of pumice and lithics lapilli. Below this layer, there's another small PFD bed that varies in thickness across the exposed outcrop (9-11cm), moderately sorted, angular to sub-angular pumice, highly vesicular, but small circular vesicles. Key characteristics; banded pumice as big as 15cm in diameter, pumice also contains sanidine crystals and obsidian.

Volcán de Fasnia (LaGro)

The description of a ~250 m long section near the Volcán de Fasnia (Montaña de Fasnia), on the northeastern flank of the Las Cañadas caldera, allowed the recognition of 4 sequences comprising pumice fall, ashfall and ignimbrites, separated by dark coloured scoria deposits. The lateral and vertical correlation of these sequences is hindered due to their discontinuity, but a stratigraphic superposition from SW to NE is estimated based on consistent dips towards northeast.

In this location, the lowermost sequence comprises a pumice fall (PFD) and a stratified pyroclastic density current (PDC) deposit, making up around 5 meters of outcrop thickness. The basal PFD overlaps a scoria deposit (but the contact is not exposed) and consists of 1.0-1.5 m thick whitish, homogeneous, well to moderately sorted, coarse-grained, clast supported and lithic-poor rock. Pumices are angular to subangular with average size between 1-2 cm (maximum size 4 cm) and stretched vesicles. Lithics (~1% vol.) are angular dark grey aphanitic rock with up to 1 cm. This deposit is overlapped by a 30-40 cm thick ash layer with sharp planar contact. This white ash layer corresponds to the bottom of the PDC, is matrix supported, well sorted, lithic poor (< 1% vol.) and contains sparse (1-2% vol.) fine-grained (2-5 mm) accretionary lapilli, whose content and size increases towards the top. This layer gradually transitions to a 2.0-2.5 m thick heterogeneous, layered deposit characterized by the intercalation between 5-60 cm thick lenses with changes in the proportion and size of accretionary lapilli. Ash-rich layers are matrix supported, well sorted, with subtle stratification. Accretionary lapilli-bearing layers vary from matrix to clast supported, with accretionary lapilli contents ranging from 5% to 60% vol., moderately sorted, with perfectly rounded and concentric lapilli that can reach up to 2.5 cm (avg. size 0.8-1.0 cm). The deposit is lithic-poor (~2% vol.), with angular to subangular lithic clasts usually around 1 mm size, but an increase of lithic contents can be observed towards the top, with a thin layer concentrating more angular and bigger (up to 4 cm) polimitic clasts (drak grey aphanitic rock, light grey crystalline rock, whitish-greyish phaneritic pyroxene-bearing rock). This deposit is capped by a redish paleosoil containing subangular to subrounded pumices, overlapped by a scoria deposit.

The lower PFD is the main pumice fall deposit. The base is not observed due to dip and scree cover. At the type locality, the formation is >0.35 m thick, massive to stratified, clast-supported, poorly sorted, coarse-grained. Pumice clasts are 5–60 mm (up to 40 mm near base), white, subangular to angular, with round vesicles and spiderweb-like vesicle structure.

Crystals are rare.Pumice displays composition variation observed through darker patches. It becomes more compact and consolidated downward. Lithics are 1–70 mm, grey/black with some light red (possibly hydrothermally altered), subangular to angular. The deposit is unconsolidated and fines-poor. As a distinctive field characteristic is the size of the pumice clasts being up to 60 mm diameter. Upper contact is sharp with overlying ash. Lower contact is obscured. Lateral continuity is unclear due to topography.

The upper PFD is exposed at the top of the outcrop. The type section is located along a 30° slope with limited lateral visibility due to the slope matching the dip (~33°). At the type locality, the upper PFD is 0.04 m thick, stratified, clast-supported, and well-preserved. It is moderately sorted, fine- to medium-grained, with white pumice lapilli (2–20 mm), subangular, and vesicular. The deposit is unconsolidated and fines-poor. A distinct feature is the presence of ~15% vol. lithics, which are grey to black with some light red fragments, subangular and up to 20 mm. The PFD overlies an ash fall and is capped by erosion. Contacts are sharp but exposure is limited laterally. Lateral continuity is uncertain due to dip-slope similarity. The PFD overlies an ash fall and is capped by erosion. Contacts are sharp but exposure is limited laterally. Lateral continuity is uncertain due to dip-slope similarity.

PFD-4

This fourth Pumice Fall Deposit is moderately thick and exposed below scoria-rich layers. At the type locality, it is 1.5m thick, stratifies, with normal grading, well sorted, clast-supported, and composed of sub-rounded pumice with average clast size 2.5 cm and max ~5.5 cm. The deposit is fines-poor and homogeneous. Distinct field characteristics include stretching of pumice and a base rich in accretionary lapilli, obsidian fragments and small red lithics. It lies beneath baked paleosol and scoria units, and above alternating graves and ash beds. Very sharp contacts and lateral continuity down the slope while increasing the PFD thickness.

PFD-5

At this site, the PFD consists of multiple interbedded pumice and gravel layers. The full exposed sequence is ~13.4 m. The PFD units are interbedded with gravelly pumice and show moderate to poor sorting, clast-supported, and unconsolidated. Pumice is angular to sub-rounded, vesicular to stretched, with black, red, gray lithics. Multiple pulses are present with coarse size lapilli, obsidian and oxidized red lithics. Notability, units show vertical color change (white pumice to oxidized red) and a variation of lithic content. The units are interbedded with gravel and ash. Some transitions are erosional. The sequence ends at an unconformity.