Written Direct Testimony of Clifford W. Smith, Ph.D

My name is Clifford W. Smith and I am an Emeritus Professor in Botany at the University of Hawai'i at Mānoa, 3190 Maile Way #410, Honolulu Hawai'i 96822. I have a Bachelor of Science in Botany from the University of Wales, Bangor, U.K., a Master of Science in Botany from the University of Manchester, U.K., and a Ph.D in Botany from the University of Manchester, U.K. I taught botany and biology for 32 years.

I have been studying lichens on the summit of Maunakea since 1982. A list of my publications is provided in my curriculum vitae, submitted as Exhibit A-37. I prepared the following technical report on the flora found at the proposed Thirty Meter Telescope Observatory site on the summit of Maunakea in May 2009 with a few nomenclatural amendments in 2016.

Introduction

The summit area of Mauna Kea is barren land of massive cinder cones above andesite lava flows that erupted during the last period of glaciation; the lava flows erupting below the glacier cooled without crystallizing creating a particularly dense rock (Group 70 International, Inc. 1999). The average daytime maximum air temperature is 50.1°F and the low 24.8° F; it freezes almost every night of the year (NOAA 2008). Such fluctuations are often referred to as "summer every day, winter every night." The average annual rainfall is 7.4 inches/year principally from November through April with little rain during June and July. Snow accumulates during the winter months sufficient for skiing but accumulation records have not been kept. UV radiation is intense; records from the Mauna Loa Observatory at 11,135 foot elevation are much higher than at sea level and will be higher still on the summit area of Maunakea (Bodhaine et al. 1997). Winds at the summit can reach 100 mph sufficient to abrade

vegetation from rock surfaces (Group 70 International, Inc. 1999).

In a general botanical survey of the summit area above 12,992 feet, Smith et al. (1982) recorded one species of algae, no hornworts or liverworts, possibly 12 species of moss, possibly 25 species of lichen, one fern and five flowering plants. All species occurred in very low abundance though there were very small, highly protected pockets where the lichens and mosses were common.

This survey was confined to a much smaller 40-acre area of the North Plateau.

Study Site

The study site was the area being considered for the Thirty Meter Telescope just below the summit of Maunakea, Island of Hawai'i. The area surveyed is called Area E, a 34-acre zone near the 13N Site located on the North Plateau of the Mauna Kea Science Reserve ("**MKSR**").

Methodology

We spent two days in the area walking through the whole site recording all lichens and bryophytes observed. We searched all four principal habitat types and spent some extra time investigating the small caves taking particular care not to disturb anything that looked of archaeological significance. We replaced all rocks that were picked up for examination as precisely as possible. We did disturb some of the rocks on the ground as we slid into the caves. We walked as much as possible on the large rocks and flows to prevent disturbance as well as for safety reasons.

The undersurface of 25 rocks of varying size were examined for lichens in rubble habitats. Counts were made of lichens present on the undersurface of rocks in the rubble areas to quantify abundance in these areas.

We removed small samples of all species found. Voucher specimens will be deposited

in the B. P. Bishop Museum in Honolulu, Hawai'i. Larger specimens were collected of species of whose identity we were uncertain so they could be sent to other lichen experts for confirmation of their identity.

Habitat Description

Substrate types

- Pahoehoe. - About 50% of the habitat was of this type. The general topography was essentially flat and smooth with many folds. The edges of the folds were steep and rounded. There were several areas where the flow had shattered, fallen away creating small cliff-like faces. In several areas particularly at the head of small draws that typically radiated away from the mountain top in a northerly direction, small caves were found which ranged from about one foot to almost six feet deep.
- Aa. - No aa was found in the study area.
- Ash. - Small areas of ash were found in about 10% of the area.
- Rubble of shattered stones. - This environment constituted about 40% of the habitat. Because lichens can grow on the undersurface of rocks we counted the number of rocks on their undersurface. We selected three different situations; stones that were somewhat embedded in ash, stones where subsurface stones rested on ash, and stones where there was no ash evident between or below the stones. Twenty-five stones were overturned and examined for lichens and then replaced in their original position. Stones of various sizes were examined. Lichens were found only in the group where ash was not evident. In all but one instance the only lichen found was *Lecanora polytropa* and none of the thalli were fertile.

Rock surface

There are two apparent rock types in the study area: a dense bluish coloured rock that breaks with a smooth surface with very few cracks or bubble cavities, and a brown rock with a rougher surface and numerous bubble cavities. Both are andesite rock formed under the ancient summit glacier. The rocks are acidic and low in calcium.

Topography

The overall topography is approximately 10° slope with a sharp decline to a lower plateau on the eastern side. The slope increases at the northern edge of the study.

- Site 1 has less andesite rock, at least there is less exposed smooth, blue rock, there are also several small 'draws' leading down the mountain. They do not appear to be drainage channels. They are important habitat because it is at the head of these draws that one finds good lichen habitat on the rock face and in the small caves underneath.
- Site 2 has large areas of andesite rock with many clean faces of the smooth, blue andesite rock. The draws are much wider here and do not support as good lichen communities.

Temperature

The average monthly temperatures at the summit range from -5 to 13°C (NOAA 2008).

Average Maximum Temperature (1971-2000).

	Jan	Feb Av.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(°F)	42.0 46.0	42.5	40.3	41.4	47.5	49.3	50.9	49.9	50.5	48.3	45.1	42.7
(°C)	5.6 7.8	5.8	4.6	5.2	8.6	9.6	10.5	9.9	10.3	9.1	7.3	5.9
Average Minimum Temperature												
(°F)	26.3 28.4	26.1	24.9	26.2	29.0	29.4	30.3	30.9	31.3	29.5	27.8	27.6

(°C)	-3.2	-3.3	-3.9	-3.2	-1.7	-1.4	-0.9	-0.6	-0.4	-1.4	-2.3	-2.4
	-2.0											

There is a notable, as yet unmeasured, difference in the temperature of exposed (hot) and shaded (cold) areas of rock faces. The difference is quite abrupt particularly where the aspect of the rock face changes abruptly.

Rainfall (NOAA 2008)

Average Precipitation (1971-2000)

	Jan Av.	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(in.)	0.85	0.15	1.07	0.48	0.97	0.12	0.20	0.75	0.62	0.53	1.26	0.42
	7.41											
(mm)	216	38	272	122	246	30	51	190	157	135	320	107
	1882											

Species List

Lichens

Acarospora c.f. depressa.

Small light brown areoles (<3 mm diam.).

Not fertile.

On the underside of a 15 x 7 cm piece of rubble.

Probably much more common lower down.

Candelariella cf. vitellina

Orange crust rarely more than 1 cm diam. of compact rounded areoles or isolated apothecia.

Not fertile.

On consolidated ash or *Grimmia* tussocks in well-sheltered situations exposed to light but not in positions where it is exposed to full sunlight for long periods.

A cosmopolitan species on siliceous and non-calcareous rock.

The size and clumped, almost erect, nature of the areoles and their separation from the apothecia

might suggest that this is a different species. However, the K- staining reaction clearly excludes the possibility that it is a species of *Caloplaca.* The somewhat unusual growth form may be a consequence of the unfavorable environment where the squamules rarely divide but continue to grow.

Lecanora polytropa

Thallus of small, often indistinct areoles to somewhat continuous yellow-green crusts with frequent apothecia. The apothecia sessile, the margin the same color as the thallus, the disc paler with a somewhat greasy appearance, often partly or completely grayish to black, frequently completely overlapping the areole.

On rock in cracks or on *Grimmia* tussocks in open situations and at the mouth of overhangs. It is also found on the undersurface of rocks in the rubble areas.

A cosmopolitan species on siliceous rock.

The most widely distributed species in the study area.

Lecanora sp.

One small (1 cm diam.) thallus of compact white squamules most covered with large apothecia with concolorous margins and 1 mm diam., light buff discs.

On a small rock chip among consolidated ash amongst Grimmia.

Lepraria incana

A thin crust of small gray to blue-gray granules with a delicate intervening web of white hyphae.

In deep shade of small caves.

Generally on the floor but toward the cave mouth also on the roof. The species prefers shaded habitats and is not tolerant of direct rainfall. It requires the very humid conditions found in the protected caves and can absorbed moisture when the relative humidity is higher than 70 percent.

Cosmopolitan.

Confirmation awaiting chemistry.

Pseudephebe minuscula

Colonies up to 5 cm diam., black, richly branched, prostrate, closely appressed to the rock face,

thread-like, wiry.

Not fertile.

On exposed, N-facing, vertical or almost so, rock faces. It was only found on the smooth rock face of exposed andesite rock. Common on sheer north-facing rocks at the head of the small draws and occasionally more open areas.

Arctic-alpine, circumboreal.

Rhizocarpon geographicum

An immediately recognizable species of small yellow areoles surrounded by a black hypothallus, with occasional apothecia in the middle or to the edge of the areoles.

On exposed, N-facing, vertical or almost so, rock faces. It was only found on the smooth face of exposed andesite rock. Cosmopolitan. Arctic-alpine, montane in the tropics.

Not common.

~~*Rhizocarpon sp.*~~ ***Lecidea baileyi***

Small colonies (1-2 cm diam.) of brown, shiny areoles <0.5 mm diam., interspersed with a black hypothallus.

On exposed, N-facing, vertical or almost so, rock faces. It was only found on the smooth rock face of exposed andesite rock.

Reminiscent of *R. hochstetteri* but no apothecia were found.

Umbilicaria ~~*aprina*~~ *decussata*

Small (1-2 cm diam.), gray to black thalli generally closely appressed to the rock face but with ascending edges where crowded, the upper surface with large white crystals particularly along ridges. Attached at one point only (umbilicate). Not fertile.

On exposed, N-facing, vertical or almost so, rock faces. It was only found on the smooth rock face of exposed andesite rock.

Abundant in a few areas. Also known in greater abundance and size particularly where protected from continuous insolation in the summit area down to at least 3660 m.

Cosmopolitan.

The thalli are attached along cracks or in a few small gas pockets on the rock surface.

Umbilicaria hirsuta

Very similar to *U. ~~aprina~~ decussata* but the upper surface is brown and there are no crystals on the upper surface.

Only one colony was found mixed in with *U aprina.*

A cosmopolitan species found in greater abundance at lower elevations.

Lichen Abundance Estimates:

Counts of lichens present on the undersurface of 25 rocks in the rubble areas.

Embedded rocks. No lichens in two separate situations.

Rocks over ash. *Lecanora polytropa* under two rocks in one sample, 0 in the other.

Rocks not over apparent ash. *Lecanora polytropa* under 10 or 12 rocks in the two samples as well as being on rocks under the rocks examined. *Acarospora sp.* under one rock.

Bryophytes

Grimmia pulvinatum

Small tussocks of grayish moss with black leaves and a fine white terminal hair.

On consolidated ash in well-sheltered situations exposed to light but not in positions where it is exposed to full sunlight for long periods.

Pohlia cruda

Small tussocks of green moss often with an orange tinge.

On consolidated ash in well-sheltered situations exposed to light but not in positions where it is exposed to full sunlight for long periods.

General Comments

- The lichens and bryophytes are confined to protected habitats almost always on the north-facing sides of rocks or the head of small collapsed lava tubes.
- There is an extremely low cover (<1 percent) and diversity of lichens (10 species out of a currently known 612 species in the islands) and bryophytes (2 species out of a currently

known 273 species in the islands) in the area. In sheltered, amenable habitats, lichens are locally common.

- The distribution of the different lichens is thought to reflect their ability to tolerate UV irradiation, overall light intensity and the availability of water, both liquid and gaseous.
- There is a marked difference in the distribution of the various lichens. The dark to black species *(~~Rhizocarpon hochstetteri~~ Lecidea baileyi, Pseudephebe miniscula, Umbilicaria ~~aprina~~ decussata* and *U hirsuta)* are found on the open face of northern facing rocks, *(Candelariella vitellina, Lecanora polytropa* and *Lecanora sp.)* at the base of northern facing rocks and *(Lepraria incana)* on the roof of the small lava tubes or deeper inside the tube). The presence of the dark species in the most exposed inhabited areas is in keeping with McEvoy, M., Gauslaa, Y. & Solhaug, K.A. (2007) finding that melanic pigments play a photoprotective role in light acclimation. The other species do not have such protection though the apothecia and areoles of *L. polytropa* are often light to dark grey in more exposed situations. *Lepraria* species frequently grow in protected shaded and humid habitats.
- Concise determinations of some species is not possible under the time constraints of this study even though fruiting bodies may be present. Species growing in such severe habitats, particularly those growing on rocks, produce spores only during favorable conditions. The only sure way of finding good specimens would be to conduct monthly collections for at least one year.
- None of the plants show evidence of feeding and there do not appear to be any obligate herbivores present. Therefore, the plants present do not appear to be necessary to support any herbivore trophic level.

- None of the lichen species present contain cyanobacteria so if nitrogen fixation is taking place up there none of it comes from lichens. Lichens on lava flows down below contribute to the nitrogen budget particularly the very common *Stereocaulon vulcani.*

Recommendations

- Site E2, the upper, more southerly footprint site being considered for Project construction is the preferred site from a cryptogamic point of view. The number of species is lower and the abundance of those present is lower. There is less sheltered habitat present.
- There is a greater abundance of lichens at the same elevation adjacent to the proposed sites where there are mounds of rocks rather than the solid flows present in the proposed sites.

Conclusions

- The TMT project will not have a significant adverse impact on the flora on Maunakea.
- There is a very low diversity and cover of plants in the study area.
- All of the species are found at somewhat lower elevations at least on the southern side of the mountain. None of the species are unique to Hawai'i. There are no endangered or threatened species of flora at the TMT project site. There are no endangered or threatened species of cryptogamic flora at the TMT project site.
- Lichens and bryophytes are generally confined to the northerly aspect of rocks or under overhangs and even then the abundance of species is much higher in those facing north.
- The vascular plants appear to be confined to the western side of the larger pahoehoe flows.
- It was gratifying to note that much of the rubbish that was seen in the 1982 Survey of the summit area had been removed.

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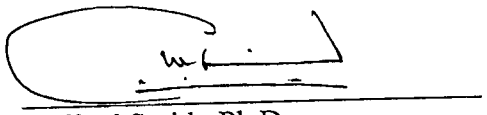

Clifford Smith, Ph.D.