UNDERSTANDING THE GEOLOGIC CONTEXT OF THE APOLLO 11 BASALT SUITE BY SYNTHESIZING REMOTE SENSING DATA AND SAMPLE GEOCHEMISTRY

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Introduction: The Apollo 11 samples are lacking in field data and documentation as the goal of this mission was get as much done as possible as quickly as possible to ensure a successful mission. Only two basalt samples were able to verifiably be located in specific photographs (10022 and 10032) [1].

The rest of the samples were collected in two areas, designated as “bulk” and “documented.” There have been many papers characterizing the geochemistry of the samples and there has been plenty of remote sensing research on the region, but little work has been done to integrate the two sources of information for Apollo 11. This type of study was done extensively for Apollo 17 [2], but given the lack of field data for Apollo 11, this task becomes more difficult.

Background: The local surface geology of the Apollo 11 is relatively simple: the region is situated on an Imbrian Mare (Im3) roughly forty meters awar from the closest highlands and is to the southeast of Imbrian Mare 4 (Im4) [3]. This unit forms relatively flat, smooth surfaces with most of the variation deriving from impact craters at a much lower elevation than the surrounded highlands [3,4]. The landing site was situated approximately 400 meters west of the sharp-rimmed West Crater and 60 meters west of Little West Crater [5]. The landing site is also located to the north of a small, shallow crater known as double crater. Figure 1 provides a regional map the Apollo 11 site (from [Iqbal et al. 2019]).

Sample Data: The Apollo 11 basalts have been subdivided into 5 groups (A, B1, B2, B3, D; [6]) based on whole-rock chemistry (Fig 2). These were erupted in distinct phases: A compilation of all previously determined Apollo 11 high-Ti basaltes indicates four distinct phases of volcanism at 3.85 ± 0.02 Ga (Group B2), 3.71 ± 0.02 Ga (Group B3), 3.67 ± 0.02 Ga (Group B1), and 3.59 ± 0.04 Ga (Group A) [7,8]. Group D basalts compromise only three members and an Ar-Ar age of ~3.85 Ga has been reported [9].

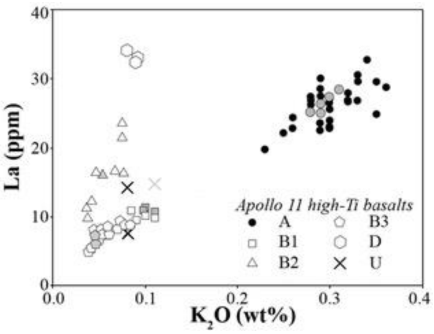

Figure 2. Apollo 11 Basalt Compositions [6]

It is theorized that most of the Apollo 11 samples are ejecta from West Crater, with various models attempting to decipher the stratigraphy [10]. The relative stratigraphy is approximated on the basis of abundance and age data as shown in Figure 3 [3]. It is currently hypthosized that the type A basalts are the surficial units of the flow because they are the youngest and most abundant of the Apollo 11 basalts [3].

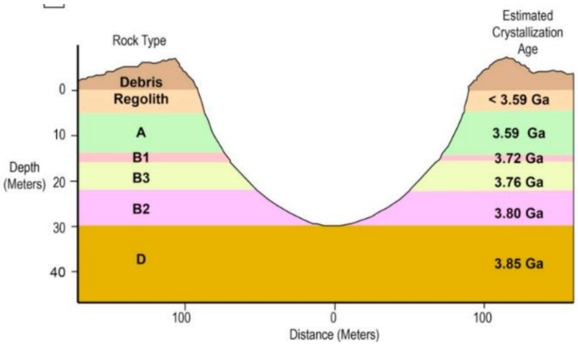

Figure 3. Basalt Sequence of West Crater (Iqbal et al 2019) (Beaty and Albee 1980)

While only two basalt samples were individually located (10022 and 10032), it is possible to differentiate the basalts based on the area where they were located. The “bulk sample” area was located northwest of the Lunar Module (LM) and the “documented sample” area was taken south of the LM. The documented sample basalts include 10003, 10017, 10020, 10062, 10069, and 10071. The bulk sample includes basalts 10044, 10045, 10047, 10049, 10050, 10057, 10058, and 10092 [5]. There represent all of the Apollo 11 basalts that are hand-sized samples, allowing for more representative whole-rock composition data to be derived compared to rocklets from regolith samples.

Taking average compositions of these hand specimen basalt samples, type A has the highest TiO_2 with an average of 11.23 percent weight, followed by the groups B1, B2, and B3 with average percent weights of 9.40, 10.55, and 10.92 respectively. There are no type D hand-sized samples, so those will not be included in this assessment [11].

Synthesis: Combining the geochemistry of the basalt samples with remote sensing data from the Lunar

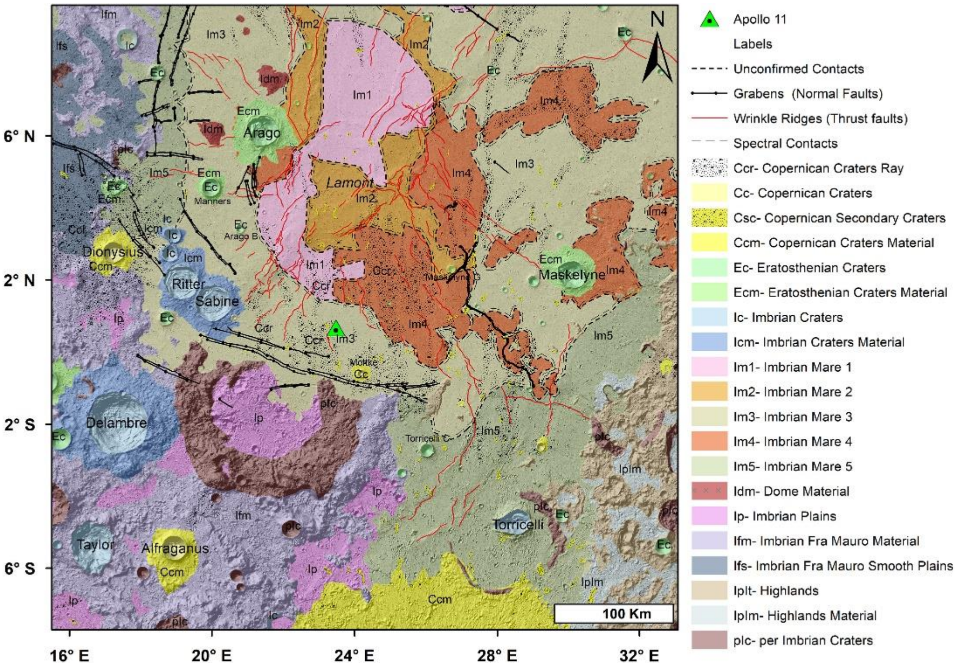

Fig. 1. Geologic Map of Southwestern Mare Tranquilitatis from Iqbal et. al 2019

Reconannaisance Orbiter and Clementine missions provides a novel understanding of the Apollo 11 landing site. Most notably, through Clementine TiO_2 abudance and Lunar Orbiter Laser Altimiter (LOLA) measurements. Clementine TiO_2 data (Fig. 4) indicates that Im4 has a lower Ti content than the other surrounding mare [3]. Specifically, Im4 has a TiO_2 of ~7-10% which, suggests a type B1 surficial unit for Im4. LOLA data show that, with the exception of wrinkle ridges, Im4 is at a lower elevation than Im3 (Fig. 5). These data suggest that Im3 is a younger lava flow that overlays Im4.

Furthermore, the surficial unit of Im3 can be described as type A based on the TiO_2 of ~11-12%. Furthermore, the mare unit age data presented in Iqbal et al. 2019 further reinforces this notion, for they calcuted Im3 be 3.61 Ga of Im3 [3], which is consistent with the age data for the type A basalts.

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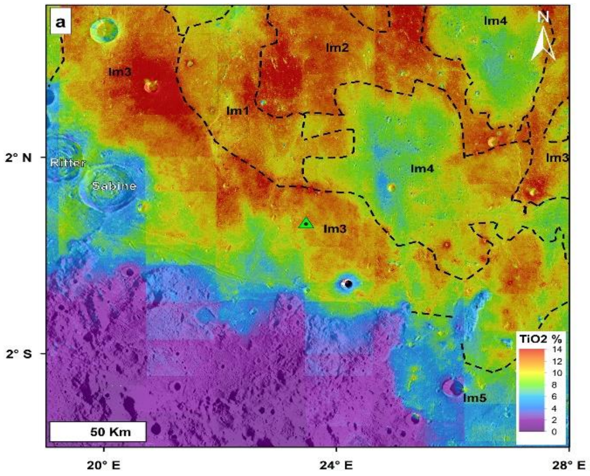

Figure 4. Clementine TiO_2 abundance of Apollo 11 Landing Site (Iqbal et. al)

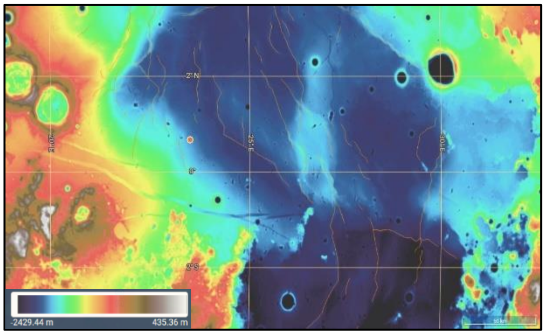

Figure 5. Lunar Reconaissance Orbiter SLDEM2015 (+ LOLA) Elevation Map of the Apollo 11 Landing Site. The Orange Dot represents the LM