

**MATURATION RATE OF IMMATURE ZONE IN TAURUS-LITTROW REGOLITH DEEP DRILL CORE ESTIMATED AT ONE 0.243 Is/FeO UNIT PER MYR WITH NEARLY EQUAL SOLAR WIND AND U+TH ALPHA DECAY RADIATION. H. H. Schmitt<sup>1</sup>, University of Wisconsin-Madison, P. O. Box 90730, Albuquerque, NM 87199, hhschmitt@earthlink.net.**

**Introduction:** The ~290 cm deep drill core (70001/9) obtained on Apollo 17 consists of 14 distinct regolith ejecta zones (Table 1), 10 to 55 cm in thickness. These zones are defined by Is/FeO maturity data [1], petrography [2,3,4,5,], chemistry [6, 7, 8], isotopic variations in volatiles [9], and cosmic ray exposure ages [10]. The combined data for the immature zone T appear to allow the determination of a rate of change of Is/FeO due to solar wind proton radiation at  $1 \times 10^{-3}$  MeV to ~10 GeV [11] and U+Th alpha decay radiation at 9-36 MeV [12, 13). Although the U+Th decay contribution to Is/FeO has decreased with time, measured Is/FeO values represent the accumulated effects of the two radiation sources.

Zone	Depth (±2 cm)	BIs/FeO ± 5% [1]	ΔIs/FeO (Est.) [1]	<sup>1</sup> Typ e	TiO <sub>2</sub> (%) [7]
70181	<5	56	16	Ibt	
<sup>3</sup> S	0-10 (70009)	44	9	Ibt	8.3
<sup>3</sup> S*	10-20 (70009)	47	11	Ibt	8.5
T	20-60 (70008)	10	45	Ibt	9.8 9.1
U	60-80 (70007)	30	8	Ibt	
<sup>3</sup> V	80-95 (70007)	43	12	Ibt	6 7.23
<sup>3</sup> V*	95-115 (70006)	45	18	Ibt + SH	6.2
<sup>3</sup> W	115-155 (70006)	70	34	Ibt	5.4 5.8
<sup>3</sup> W*	155-170 (70005)	75	15	Ibt	
<sup>3</sup> X	170-190 (70004)	45	47	SH + Ibt	5.7 6
<sup>3</sup> X*	190-200 (70004)	60	29	SH + Ibt	
Y	200-255 (70003-4)	39	58	SH + Ibt	5.7 5.5
Z	255~277 (70002)	49	56	SH + Ibt	5.8
<sup>3</sup> Z*	277-287 (70001)	<38	>20	SH + Ibt	5.6
Z**	287-290+	BIs/FeO + ΔIs/FeO = 107		SH + Ibt	5.8

Table 1. Regolith zone definition and related data.

<sup>1</sup> (Ibt = ilmenite basalt regolith; SH = Sculptured Hills regolith)

Identification of most source craters for the deep drill core regolith ejecta zones is possible, using relative crater ages determined from personal *in situ* observation, diameter/depth ratios [14], and

petrographic data correlation. Source crater correlation will be reported separately.

Close examination of the Is/FeO patterns plotted for the deep drill core (Fig. 1) shows that most zones have a minimum background Is/FeO level (BIs/FeO), defined by the Is/FeO minima of superposed saw tooth maxima. Is/FeO (ΔIs/FeO) saw tooth peaks in Fig. 1 are interpreted as being variable, post-deposition exposure of regolith with the zone's BIs/FeO by local small impacts. Regolith ejected by another local impact then returns Is/FeO to the zone's original BIs/FeO level and buries the previous ΔIs/FeO peak.

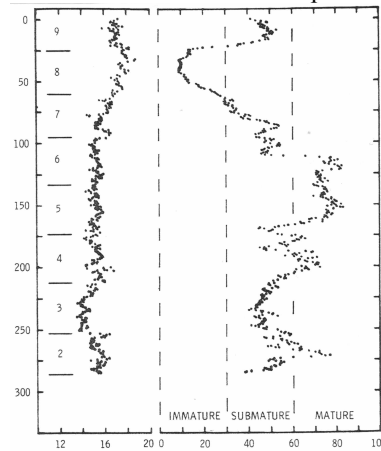


Fig. 1 Values for FeO (left) and Is/FeO (right) for Apollo 17 Deep drill core [1].

**Impact Transport of regolith ejecta:** As a consequence of the sharp difference in geotechnical properties between surface regolith and underlying bedrock and broken bedrock, plus the lack of a lunar atmosphere, a large impact ejects regolith at high but decreasing velocities (radial impact energy dissipation) in an outwardly expanding, truncated inverted cone [15] that transitions to into a parabolic arch. Before deposition as a single regolith ejecta zone the deep drill core site, a given regolith ejecta zone's BIs/FeO appears to result from turbulent mixing during ballistic transport of sampled portions of the regolith strata at the zone's source crater location. Integration of BIs/FeOs and other characteristics of the sampled source crater regolith zones apparently reflect ballistic turbulence within the parabolic arch of regolith ejected from the source crater.

**Rate of Change of Is/FeO:** If the regolith ejecta from a source crater included only one layer within the accumulate strata, it would be possible to calculate the rate of change in Is/FeO in that zone, given the total of BIs/FeO and ΔIs/FeO values of the zone and its cosmic

ray exposure age. The third regolith ejecta zone down in the deep drill core (zone T, 20-60 cm,  $\text{BIs/FeO} = 10$ ,  $\Delta\text{Is/FeO} = 45$  [1]) appears to represent a single regolith accumulation and may be ideal for a rate of change calculation. Zone T has the least mature regolith ejecta as well as having the most symmetrical  $\text{Is/FeO}$  pattern (Fig 1). In addition, zone T can be correlated petrologically with ejecta produced by the formation of the Central Crater Cluster south of the deep drill site. Further, the immaturity of zone T, its continuous pattern of  $\Delta\text{Is/FeO}$  increase, and its high fragment content suggests that the Crater Cluster impacts removed nearly all of the pre-impact regolith and that no other superposed regolith ejecta from other locations was present.

Zone T's reported cosmic ray exposure age is 330 Myr [16], or 321 Myr when corrected for additional exposure after being buried by less than  $80 \text{ g/cm}^2$  [17] of younger regolith ejecta. Also, the relative age of the Crater Cluster is clearly less than the age of the reported factor of 2.17 change in solar wind energy at  $\sim 500$  Myr ago [18], and the effect of this change can be ignored in this calculation.

Zone T also consists of high ilmenite regolith with a  $\text{TiO}_2$  content of  $\sim 9.5\%$  (Table 1, Column 6). Comparison of 31 Apollo 17 regolith samples'  $\text{Is/FeO}$  values (other than those of the deep drill core) indicates that higher ilmenite ( $\text{TiO}_2$ ) attenuates maturation [19]. The highest  $\text{Is/FeO}$  value for a representative low  $\text{TiO}_2$  (1.4 %) regolith sample (73121 from young light mantle) is 1.39 times greater than the  $\text{Is/FeO}$  value for a representative high  $\text{TiO}_2$  (8.11 %) regolith sample (70181 from relatively older dark mantle) [7]. Agglutinate content of the two samples are both high 42 and 56 [7], respectively.

To compensate for ilmenite attenuation, zone T's  $\text{BIs/FeO}$  and  $\Delta\text{Is/FeO}$  should be increased by a factor of about 1.39 to make high  $\text{TiO}_2$  regolith  $\text{Is/FeO}$  values compatible with the actual maturation rate. For zone T, this adjustment gives  $\text{BIs/FeO} = 14$  and  $\Delta\text{Is/FeO} = 64$ .

Calculation of  $\Delta\text{Is/FeO} / \text{Myr}$  for zone T, therefore, can be made as follows:

1.  $\text{BIs/FeO} + \Delta\text{Is/FeO} = 78$
2.  $\text{BIs/FeO} + \Delta\text{Is/FeO} / 321 \text{ Myr} = 0.243$
3.  $\text{Is/FeO} / \text{Myr} = 0.243$

$\text{Is/FeO} / \text{Myr} = 0.243$  will be referred to as the "new"  $\text{Is/FeO} / \text{Myr}$ . Determination of "old"  $\text{Is/FeO} / \text{Myr}$ s to account for a lower solar wind energy before about 500 Myr ago is more complex and will be reported separately. The contribution of alpha decay of finely disseminated U and Th varies from zone to zone. That contribution would not be affected by the change in solar wind but will decline over time.

#### Uranium and Thorium Effect on $\text{Is/FeO}$ :

Fig. 2 is a plot of U+Th content vs.  $\text{BIs/FeO} + \Delta\text{Is/FeO}$  for those zones for which U+Th data is

available. The apparent linear correlation between the two variables has a  $\text{BIs/FeO} + \Delta\text{Is/FeO}$  to U+Th slope of  $\sim 43$  for those analyses provided in [8]. As  $\text{BIs/FeO} + \Delta\text{Is/FeO}$  for zone T = 78 and  $\text{U+Th} = 0.999$ , the alpha particle radiation contribution to  $\text{BIs/FeO} + \Delta\text{Is/FeO} = \sim 43$  and that of solar wind protons =  $\sim 43$ . Also, half of the new  $\text{Is/FeO} / \text{Myr} = 0.243$  for zone T results from roughly a 0.134 component from both the solar wind and U+Th alpha decay. The solar wind component will decrease by a factor of 2.17 to about 0.0618 for zones deposited prior to the increase in solar wind energy around 500 Myr ago. U and Th alpha decay's contribution to regolith  $\text{Is/FeO}$  needs to be added to that of space weathering related to solar wind protons.

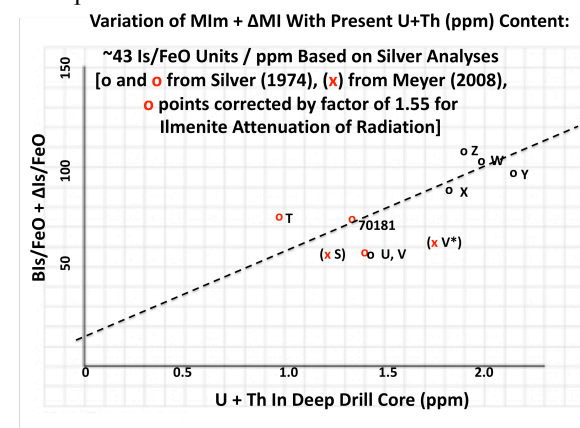


Fig. 2 Plot of U+Th content vs.  $\text{BIs/FeO} + \Delta\text{Is/FeO}$  for deep drill core regolith ejecta zones based on reported data [1,8].

**Comments:** The value of 0.243 for zone T's new  $\text{Is/FeO} / \text{Myr}$  includes several potential sources for error, including issues with loss of cosmic ray spallation isotopes [16] during maturation.

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