TABLE 1. Locations of sites where samples were collected and a brief description of the materials collected.

Site Name	Location	Rocks Reported
Phnom Krom (Quarry) (8 samples)	10 km SSW of Siem Reap (Angkor Wat)	Compact cinerites, ferrugenous scoria, pink rhyolitic lavas, dark cinerous sandstones, and various volcanic conglomerates
Phnom Baset (Quarry) (2 samples)	22 km WNW of Phnom Penh	Granite, fine-grained, leucocratic, white quartz vein
Phnom Chetares (1 sample)	30 km NW of Phnom Penh	Jointed polychrome jasperites, subvertical schists
Chealea Village Group (7 samples)	38 km N of Phnom Penh	Devitrified pyromeride, rhyolite, white fluidal rhyolite, rhyolitic breccias, siliceous dark dacite
Phnom Batheay (2 samples)	46 km N of Phnom Penh	Upper Indosinias sandstone, vein of acidic rhyolitic rock
Tmat Pong Group (Quarry) (2 samples)	26 km W of Phnom Penh	Rhyolitic, weathered whitish, sometimes fluidal
Phnom Chiso (Quarry) (3 samples)	45 km S of Phnom Penh	Massive crystalline sandstone, intensely eroded black schist
Tonle Bati Massif (1 sample)	33 km SSW of Phnom Penh	Granite, fine-to-medium grained, pseudo-vortical biotite flames, black slaty schists

Cambodian equivalents of the U.S. Departments of Commerce, Interior, State, and Defense. For support in achieving this "diplomatic" objective we are indebted to Thach Xoval Say, Vice-Director, Dept. of Mines and Geology, Sov Chivkun, Director, Dept. of Geology and Mines, and Ith Praing, Vice Minister, Ministry of Industry. We were restricted from visiting sites that were "off limits" due either to unknown locations of land mines or known locations of military bases.

Our scientific objectives were to find impact or shock metamorphosed rocks unambiguously related to the Tonle Sap basin, to collect samples of rocks that may represent those melted to produce Australasian tektites, and to learn as much as possible about Cambodian geology. Using 1:200,000-scale geologic maps with fairly detailed descriptions of the rock units shown [2], we selected a number of acceptable "phnoms" (hills that rise abruptly out of the surrounding plain) that may contain rocks affected by the postulated Tonle Sap impact. A map of central Cambodia is shown in Fig. 1, and the locations of sites where samples were collected are indicated. A list of those sites, together with a description of the rocks reported to be present at each site [2], is given in Table 1. No obviously shock-metamorphosed or suevite-like rocks were observed. Recent alluvium surrounding Tonle Sap is judged to be lake sediment deposited when the lake surface was at a higher elevation.

Acknowledgment: Support provided by the Barringer Crater Company is gratefully acknowledged.

References: [1] Hartung J. B. (1990) *Meteoritics, 25,* 369–370. [2] Dottin O. (1972) *Carte Geologique de Reconnaissance a 1/200,000,* Republique Khmere, Phnom Penh, 41 pp., and Siemreap, 16 pp., Editions du Bureau de Recherches Geologiques Minieres, Paris. [3] Rasmussen W. C. and Bradford G. M. (1977) *Ground-Water Resources of Cambodia.* Geological Survey Water-Supply Paper 1608-P, 122 pp., 3 plates.

S36-91 N93-10148 475183 P 2

THE DISTRIBUTION AND MODES OF OCCURRENCE OF IMPACT MELT AT LUNAR CRATERS. B. Ray Hawke[1] and J. W. Head[2], [1]Planetary Geosciences, SOEST, University of Hawaii, Honolulu HI 96822, USA, [2]Department of Geological Sciences, Brown University, Providence RI 02912, USA.

HI782556 BI720314

Introduction: Numerous studies of the returned lunar samples [1–4] as well as geologic and remote-sensing investigations [5,6] have emphasized the importance of impact melts on the surface of the Moon. Information concerning the distribution and relative volumes is important for (1) an improved understanding of cratering processes, (2) kinetic energy estimates and energy partitioning studies, (3) the proper interpretation of melt-bearing lunar samples,and (4) comparative planetology studies. The identification of major flows of fluidized material associated with impact craters on the surface of Venus has increased interest in impact melt flows on the other terrestrial planets. For a number of years, we have been investigating the distribution, modes of occurrence, and relative and absolute amounts of impact melt associated with lunar craters as well as the manner in which melt volumes vary as a function of crater size, morphology, and target characteristics. The purpose of this paper is to present the results of this effort.

Method: Impact melt deposits were identified using the criteria established by Howard and Wilshire [5] and Hawke and Head [6–8]. Qualitative estimates were made and trends were established utilizing a population of over 100 fresh impact craters that was characterized in a previous paper [6], plus additional lunar craters for which adequate Lunar Orbiter and Apollo photography exists. Quantitative determinations of impact melt volumes were made for those craters for which high-quality topographic data are available from Lunar Topographic Orthophotomaps.

Results and Discussion:

Melt occurrence as a function of crater size and morphology. Impact melt is more common at fresh simple craters (D < ~15 km) than has previously been thought. The smallest extensively studied crater with interior melt is 750 m in diameter, but we have noted the occurrence of even smaller melt-containing craters. At very small craters (D < 2 km), impact melts typically occur as narrow ponds of low-albedo material on crater floors, less common dark streaks on walls, and very thin discontinuous veneers around the rim crests. The melt deposits associated with slightly larger simple craters (D = 2–7 km) are similar but more abundant than those at smaller craters. Shallow ponds often occur among the small floor hummocks, and hard-rock veneers cover much of the crater floors. It appears that some of the melt flowed onto the floor from the lower portions of the crater walls and embayed clastic debris emplaced by mass wasting from the crater walls. Though some minor wall failure has occurred at craters in this size range, the positions of these craters on depth-diameter plots indicate that there has been very little, if any, reduction in depth [8–10].

Interior melt volumes are quite variable in fresh craters from 7 to 12 km in diameter. These deposits range from unobserved or present in only trace amounts to quite abundant. Extensive deposits of exterior melt are first observed around craters near the upper limit of this size range [6,8].

Numerous workers have documented the changes in lunar crater morphology and morphometry, which start at a diameter of about 15 km as smaller, simple craters undergo a transition to larger, complex craters that exhibit central peaks and wall terraces [e.g., 9,10]. It appears that the crater modification processes operative at craters between 15 and 25 km in diameter influence melt deposit morphologies and abundances. While most fresh primary craters in this diameter range for which adequate photography exists do contain at least some melt, the amounts are extremely variable. Dawes (D = 17 km) is typical of craters in this size range. Significant accumulations of impact melt are restricted to a small area immediately east of the central peak [7]. Additional melt was probably present initially but was buried by scallop material slumped onto the crater floor during the modification stage of the impact cratering event. Fresh craters in this size range that exhibit little or no interior melt are generally characterized by the presence of extensively scalloped walls and/or swirl-textured floors, features indicative of pervasive wall failure [7,8]. The results of our analysis of the interior morphologies of these craters indicate that much of the interior melt was totally buried by scallop material. We conclude that the variable amounts of interior melt associated with craters in this size range can best be explained by differences in the degree and style of wall failure.

Fresh impact craters over 25–30 km in diameter are extensively modified and exhibit terraced walls, central peaks, and flat floors with abundant deposits of impact melt. Wall failure has been more extensive and deep-seated at the larger terraced-walled craters, and little melt appears to have been buried during the modification stage. The results of detailed mapping of interior and exterior melt distributions indicate that ponded material becomes relatively more abundant on the floors and rims of these larger craters [8].

Exterior melt volumes as a function of crater diameter. Previous work has emphasized the role of oblique impact and preexisting topography in controlling the distribution and amounts of exterior melts [5,6,8]. While it is clear that these factors do cause variable amounts of melt to be emplaced on crater rims, a variety of evidence indicates that relatively greater quantities of melt are present on the rims of larger craters: (1) the dominance of large exterior melt ponds over flows and hard-rock veneer at craters over 50 km in diameter [6,8]; (2) the tendency for melts to occur at greater distances from the parent craters as a function of crater size; (3) the observation that exterior melt ponds are larger and more widespread at larger craters; and (4) quantitative estimates of melt volumes, which indicate that relatively more melt is present on the rims of larger structures. Even so, this may not imply that a greater percentage of the total melt has been ejected since the total amount of melt generated was also relatively greater at larger structures [8].

Interior melt volumes as a function of crater diameter. There also appears to be a systematic variation in the amounts of molten material in crater interiors. Since the extent and thicknesses of the ponded material on crater floors tend to increase as a function of crater size, more melt may be present in the interiors of larger craters. Support is provided by quantitative estimates of interior melt volumes for specific craters where detailed topographic data exist [11,12]. A similar trend has been noted for the impact melt volumes associated with terrestrial impact structures [13,14].

Influence of substrate on melt generation. Numerous cratering studies have demonstrated the importance of target characteristics in determining the morphology of lunar craters [e.g., 15,16]. Therefore, we made an attempt to determine the influence of substrate on the relative amounts of impact melt associated with craters in highland vs. mare terrains. A comparison of the mapped interior melt deposits in similar-sized craters (D < 50 km) suggests that highland craters contain melts in amounts either equal to or less than the amounts present in mare craters. This observation does not necessarily indicate that more melt was generated by impact into mare targets. The observation could be explained by one or more of the following: (1) for a given impact energy, larger craters may be formed in the highlands relative to the mare; (2) the style and degree of wall failure is known to be dependent on terrain, topography, and substrate [15]; and (3) a limited amount of evidence suggests that more melt was ejected from highland craters.

References: [1] Simonds C. et al. (1976) *Am. Mineral., 61*, 569. [2] Simonds C. et al. (1977) *Proc. LSC 8th*, 1869. [3] Taylor S. R. (1982) *Planetary Science: A Lunar Perspective*, 481 pp. [4] Spudis P. et al. (1991) *Proc. LPSC, Vol. 21*, 151. [5] Howard K. and Wilshire H. (1975) *J. Res. U.S. Geol. Survey, 3*, 237. [6] Hawke B. and Head J. (1977) *Impact and Explosion Cratering*, 815. [7] Hawke B. and Head J. (1977) *LSC VIII*, 415. [8] Hawke B. and Head J. (1979) *LPSC X*, 510. [9] Wood C. and Andersson L. (1978) *Proc. LPSC 9th*, 3669. [10] Pike R. (1977) *Impact and Explosion Cratering*, 489. [11] Lange M. and Hawke B. (1979) *Conf. Lunar Highlands Crust*, 99. [12] Lange M. and Hawke B. (1980) *Proc. LPSC 10th*, 599. [13] Dence M. et al. (1977) *Impact and Explosion Cratering*, 247. [14] Grieve R. et al. (1977) *Impact and Explosion Cratering*, 791. [15] Cintala M. et al. (1977) *Proc. LSC 8th*, 3409. [16] Head J. (1976) *Proc. LSC 7th*, 2913.

LARGE IMPACTS IN THE BALTIC SHIELD WITH SPECIAL ATTENTION TO THE UPPLAND STRUCTURE. H. Henkel and R. Lilljequist, Institute for Fotogrammetry, KTH, S-10044 Stockholm and Department of Geology, University of Stockholm, S-106 91, Stockholm, Sweden.

Within the Baltic Shield several very large structures have been identified and are suspected to be of meteorite impact origin (Fig. 1 and Table 1). Some of these deeply eroded circular features will be