USING RECENT IMPACT CRATERS AS A SAMPLING MECHANISM FOR A MARS SAMPLE RETURN MISSION. T. D. Swindle[1,3], L. L. Tornabene[1], A. S. McEwen[1], and J. B. Plescia[2], [1]Lunar and Planetary Laboratory, University of Arizona, Tucson AZ 85721 USA, [2]Applied Physics Laboratory, Johns Hopkins University, 11100 Johns Hopkins Road, Laurel MD 20723 USA, [3]tswindle@u.arizona.edu.

Introduction: Recent impact craters, several of which have been identified by the presence of extensive ray systems, provide a natural tool for breaking up and extracting samples from identifiable geological units and putting them in an easily accessible deposit. Hence they provide logical targets for an early sample return mission.

The goals that would be pursued are the absolute ages of particular surfaces, the connection between remote sensing and the composition and petrology of particular lava flows, and perhaps the connection of specific craters with the well-studied martian meteorites. Determining the age or other properties of a specific crater is not a first-order goal. Rather, the crater would provide a large quantity of more-easily-sampled material from a known geologic unit.

Martian rayed craters: Although craters with extensive visible rays have long been known on many Solar System bodies, most notably the Moon, the first identification of a Martian rayed craters has only come in recent years[1, 2].

The Martian rayed craters have been discovered not because of their visual albedo, but because of distinctions in their thermal infrared signature, as measured from orbit by TES and THEMIS (Fig. 1). The low-thermal-inertia (fine-grained) material that is visible in the IR produces rays that also contain clusters of secondary craters when examined at optical wavelengths [2, 3].

The first discovered was Zunil (Fig. 2), a 10-km crater with with IR discernable rays extending ~800-900 km [2, 3] and ~10^8 secondary craters of 10 m diameter or more extending as far as ~1600 km [4]. In addition, it probably produced ~10^{10} rock fragments ≥10 cm, and even more at the slightly smaller sizes ideal for robotic sampling.

Four more definite and three probable rayed craters were discovered by [3], and yet another (now the largest known rayed crater system) was recently identified [5]. Most, though not all, of these craters are on rather young surfaces, late Hesperian or Amazonian, in the vicinity of either Elysium or Tharsis. In fact, there may be specific conditions required that make intact lava flows prime candidates to either form rays or to render them detectable [3]. Clearly, this is not a problem if the goal is to learn about Martian volcanism.

Science goals: Geochronology is an attractive objective for a sample return mission, because the questions of when processes occurred and how long they took are key to understanding the evolution of Mars. In addition, geochronology is an area in which the power of terrestrial laboratories far exceed proposed in situ techniques. Carefully targeted in situ measurements could prove useful [6], but will never approach the precision and multiple-system redundancy of laboratory measurements [7]. Two areas that would be key to unraveling Martian chronology would be determining the age of a very young lava surface and providing a point in the "middle" of Mars' history (e.g., Hesperian). Either (though not both) is possible with the selection of the proper rayed crater. Either would provide a calibration point with chronologies based on crater counts, perhaps helping determine the importance of secondary cratering in crater counts [2] and potentially providing a source for some of the Martian meteorites.

Since the rayed craters are among the youngest craters on Mars, and possess rays including numberous secondaries formed from high-speed ejecta (>1 km/s), they are likely candidate source craters for Martian meteorites [2, 3]. If, in fact, a source crater is sampled, that has the advantage of tying the vast amount of information acquired on the Martian meteorites to a specific location, providing valuable geologic context for the best characterized Martian samples to date. If the crater sampled is not a source crater for Martian meteorites, knowing the age and state of preservation of the crater may provide some clues to which craters may be source craters, and still provides a calibration point for the Martian crater production function.

Most of the rayed craters are on fairly extensive lava flows, extensive enough that they are identifiable in orbital data. Knowing the composition and mineralogy of the rocks from surface samples would provide a crucial comparison point for spectral data obtained from orbit, if not too dusty.

Note that the ideal sampling locations to take advantage of these craters would probably not be within the craters themselves. In some cases, the ground is rough, but a more serious problem is that many of them contain ponded deposits that might be impact melt. While perfect for dating a crater, such impact melt would destroy much of the information about the pre-crater geology. Nor would a sample from a ray itself or a distant cluster of secondary craters be ideal. The thermal signature of the rays themselves is produced by fine-grained material, perhaps only skin deep. Meanwhile, much of the fragmented material in or around a secondary crater would be from the terrain in which the secondary crater, not the primary, formed. Rather, optimal sampling would probably be within about one crater radius from the crater rim, where unmelted ejecta would still be abundant, such that it would provide a source of material with the composition, petrology and crystallization age of the previous surface that is not highly shocked, but any local rock either excavated by ejecta or sampled by some other mechanism would have a clear genetic relationship with the surface in which the crater formed.

Perhaps, though, the only Mars sample return missions for the next several decades will be from ancient and perhaps geochronologically complex regions, such that the ages determined by any or all isotopic systems will be difficult to tie to a particular surface. If so, one or more of these craters might be a natural location for an in situ geochronology mission [8], where the lower precision would be compensated by the confidence in what is being dated by the age(s) obtained.

Specific craters: As illustrations of the kinds of regions that could be studied with such a mission, we give more details about several of the rayed craters. Crater diameters are given in parentheses.

Zunil (10.1 km), the first rayed crater discovered, and perhaps the youngest, is located on one of the youngest surfaces on Mars, in Cerberus Fossae, home of some of the most recent volcanic and fluvial activity on Mars [2, 9].

Tomini (7.4 km) is located 1250 southwest of Elysium Mons, in a Hesperian-aged unit, near an Amazonian-age unit [3]. Zumba (3.3 km) is also Hesperian-aged, on a series of lava flows originating from Arsia Mons [3]. The yet-unnamed crater (15 km) recently discovered is on the flanks of Elysium Mons, in a lower Amazonian unit. Any of these could provide an important calibration point for the crater-based chronologies near the Hesperian/Amazonian boundary, and each has its advantages. For example, Zumba would provide a sample of material from the Tharsis Rise.

As well as the rayed craters, other relatively fresh craters would have similar advantages, although some might be too old to be candidates to for Martian meteorite source craters. For example, Hale Crater (120 x 150 km) is an Amazonian-aged crater on a terrace of the Argyre basin that appears to have triggered fluvial activity. A carefully-targeted mission to Hale could potentially address both the age of Hale and of Argyre, as well as providing material that could be used to study a relatively recent fluvial episode.

Hence fresh craters, particularly rayed craters, would be a logical target for a geologically valuable sample return to Mars.

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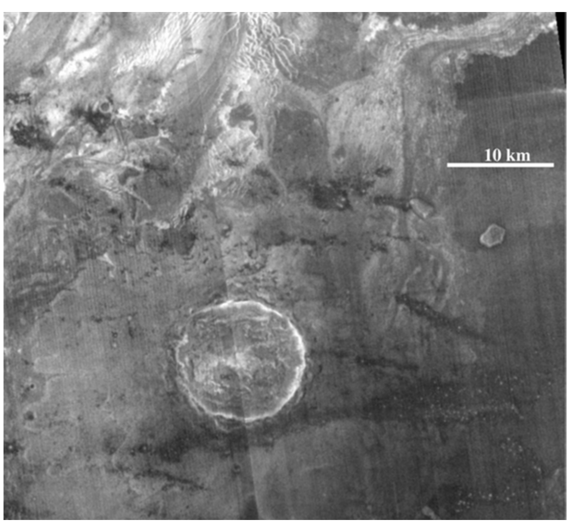

Fig. 1: Part of a mosaic of THEMIS IR images (nighttime) of the Athabasca Valles region, showing dark (relatively cool) streaks (Zunil rays) with bright (warmer) spots (interiors of larger Zunil secondaries). The scene is ~50 km wide; located SE of Athabasca Valles. North is up. From [2].

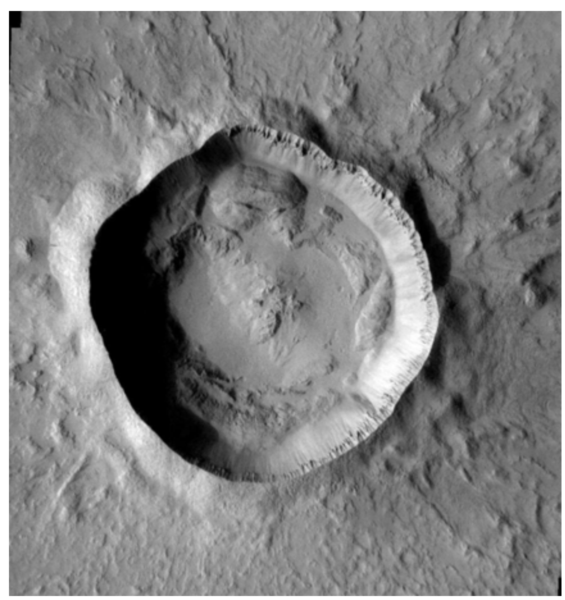

Fig. 2: Zunil crater (diameter 10.1 km), at 7.7ºN, 166ºE. North is up. From THEMIS visible image V09818024.