PINGOS, GERVIGIGARS AND MARTIAN MYSTERIES. Charles A. Wood, SN-6,
NASA Johnson Space Center, Houston, TX 77058.

Viking photography has revealed numerous small crater-topped cones that have been interpreted
as products of volcanic eruptions, or alternatively, phreatic eruptions. In a previous paper I
summarized available information on terrestrial monogenetic volcanoes that might be analogs to these
small martian cones. This paper provides similar data for two other types of terrestrial
 cratered cones (which may also be analogs to the martian cones) for which the availability of water
is a critical factor in their formation: (1) Pingos are ice-cored mounds common in terrestrial
 permafrost regions. (2) Gervigigars (called pseudocraters in the English literature) are low
energy phreatic explosion craters known only from Iceland. There is a substantial literature on
 pingos, but no systematic quantitative data on their morphology, as is required for detailed
 comparison with martian cones. Thorarinsson's classic paper5 is the major work on gervigigar; this
 note is based on that paper and my limited field investigations in Iceland in July, 1980.

Pingos (Ref. 4, 6, 7, 8, 9). According to McKay5 pingos originate from "the arching of an
imperious sheet of permanently frozen ground under pressure." Open-system pingos are formed by the freezing of water that flows downslope within or below a perma-
frost layer, whereas closed-system pingos use water derived from a freezing front that advances
into an unfrozen area completely surrounded by impervious material. The mounds created by the
 closed-system process occur on flat ground, tend to be relatively large and circular in plan, whereas
 as open-system pingos commonly are found along valley slopes, are relatively small, and often
cluster or form elongated masses. Open-system pingos in Canada occur only in continuous perma-
frost >60 m thick. Open-system pingos generally occur in discontinuous permafrost thin enough to be up-
lifted by the expansion of the freezing water. Refreezing of the overburden is frequently ac-
counted for, or form irregular summit depressions but often a relatively uniform crater results. Some craters appear to be very much wider than others, perhaps
due to thawing of the pingo's ice core and subsequent collapse of the summit. Craters are not a
diagnostic feature of pingos, however, for a survey of 1380 pingos east of the Mackenzie delta of
Canada revealed that only 24% had cratered or collapsed summits.10

Dimensions of individual pingos are scattered throughout the literature; data collected for 37
 pingos (Table 1) suggest an average basal diameter of nearly 100 m, and an average height of about
 10 m. The spacing between pingos is quite variable, ranging from rare cases of isolated pingos to
 great concentrations. Normally open-system pingos have a higher spatial density than closed-system
 examples, but one of the highest known densities (15/km2) is within the zone of continuous perma-
frost and thus are thought to be closed-system features.11

Dimensions of individual pingos are scattered throughout the literature. The cones are relatively
 small and some are no taller than 1 meter; tallest is within the zone of continuous perma-
frost, which typically equals 20% to 50% of the pingo height.7 Presumably pingo basal diameter is also related to over-
 burden (and ultimately uplift pressure of the pore ice); if so the Ho/Wo relations given in Table
 1 imply that the depth to the ice layer equals 0.02 to 0.06 times the pingo diameter.

Gervigigar (Ref. 5). In Iceland an apparently unique style of water/magma interaction produces
 small cones and sounds commonly called pseudocraters. This name is inappropriate because the craters
 are raised by pressure lack direct interaction to magma sources at depth), and additionally, many pseu-
docraters lack craters! For these reasons the Icelandic term gervigigar, as used on Icelandic geo-
logic maps, is preferred. Hundreds of gervigigar occur where a 2500 yr old lava flow crosses Lake
 Myvatn in northern Iceland. The close association of gervigigar with the young lava and the lake
 (and between lava flows and river valleys or sandur plains in other parts of Iceland) indicated to
 Thorarinsson that the cones formed by explosions of steam trapped beneath the lava. Simple thermal
 dynamic calculations by Allen12 illustrate that more than enough energy to form the craters is
 available from generation of steam, however, the water (or ice) must be very close to the surface
 (within 1/2 the thickness of the lava flow). Allen did not investigate the relation between flow
 thickness and cone size, but Thorarinsson5 noted that the largest gervigigar at Myvatn are near the
 center of the lake where the lava flow is thought to be the thinnest. At the northern limit of the
 Landsbrotsholar field of gervigigar, on the southern coast of Iceland, slabs of lava have been ro-
 tated into vertical positions, but (perhaps because the flow was too thin to allow buildup of sub-
 stantial steam pressure) there are no gervigigar mounds.

Gervigigar at Myvatn have large craters, but at Landsbrotsholar and Thjorsardalur (a gervigigar
 field stretching about 5 km along the banks of the Fossa River) they are flat-topped. Because gervi-
 gigars are quite small their dimensions cannot be readily measured on topographic maps, the data in
 Table 1 are based on measures of the Myvatn cones - the largest in Iceland. Gervigigar are usually
 highly concentrated and often overlap.

Cones on Mars (Ref. 1, 3). Dense concentrations of small cones, frequently cratered-topped,
have been found in various regions of Mars. These features have been interpreted both as cinder
 cones1,13 and as gervigigar. Quantitative data are presently available for only 20 cones in the
 Cydonia Mensae region of Mars (listed in Table 1 along with terrestrial cone comparison
data). On Mars, however, there is now considerably more data set. In terms of the information
 Table 1, terrestrial cinder cones appear to have the greatest similarity to the Cydonia cones.
 The martian cones, however, were formed in a gravitational field only 40% as strong as the
 Earth's, thus ballistic cone-forming processes (gervigigar and cinder cones) would yield cones about
 2-1/2 times wider than equal energy terrestrial eruptions. Similarly, pingos would also probably
 be larger because martian overburden could be 2-1/2 times thicker (for the same weight) than on Earth.
 In order to maintain the terrestrial Wo/Wo ratio, however, martian gervigigar and cinder cones
 must have had (a) larger volumes or (b) smaller ejection velocities. Based on crude height data, I

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previously estimated that the volume of the median size Cydonia cones is roughly 25% of the volume of median diameter terrestrial cinder cones. Thus the only way to account for the equality of terrestrial and martian $W_C/W_{CO}$ values, interpreting the Cydonia cones as cinder cones, is to postulate low energy eruptions on Mars. If, on the other hand, the Cydonia features are martian gervigigar, their estimated volumes are roughly 500 times greater than typical for Icelandic gervigigar. This abstract was accepted for publication in the abstract volume of the 3rd Coll. on Planetary Water, Oct. 1980, but was inadvertently omitted. I thank Herb Frey for critical discussions.


**TABLE 1:** AVERAGE DIMENSIONS OF SMALL CONES

<table>
<thead>
<tr>
<th>Cone Type</th>
<th>$W_C$(m)</th>
<th>$W_{CO}$(m)</th>
<th>$H_C$(m)</th>
<th>$H_{CO}$(m)</th>
<th>$D_C$(m)</th>
<th>$D_{CO}$(m)</th>
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<tbody>
<tr>
<td>Pingos</td>
<td>32/50/600</td>
<td>0.40/0.60/0.80</td>
<td>0.02/0.12/0.33</td>
<td>0.06/0.34</td>
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<tr>
<td>Gervigigars</td>
<td>38/50/200</td>
<td>0.32/0.50/0.52</td>
<td>0.04/0.08/0.20</td>
<td>0.06/0.20</td>
<td></td>
<td></td>
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<tr>
<td>Cinder Cones</td>
<td>25/50/1000</td>
<td>0.30</td>
<td>0.03/0.5</td>
<td></td>
<td></td>
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<tr>
<td>Cydonia</td>
<td>400/800/1500</td>
<td>0.33/0.41/0.51</td>
<td>0.1/0.5</td>
<td></td>
<td></td>
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</tr>
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</table>

$n$ = cone base diameter; $W_C$ = crater diameter; $H_C$ = cone height (range, mean and sample size given for column $W_C$); $D_C$ = cone spatial density, representative values in columns $W_C$. 

Below: Part of the Thgorit-sandur gervigigar field in southern Iceland. The prominent cone on the left is 10-15 m high; the low cone on the right foreground has a very shallow crater but craters are rare to absent.

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