A PINGO GROUP ON NOACHIS TERRA, MARS.

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Introduction: A number of articles have described periglacial polygonal terrains, pingos and pingo groups on Mars [1-3] connected to groundwater [4] and lake beds [5-7]. The MOC images allowed to identify details of pingo fields [8-15]. Recent HiRISE images have increased many substantial details to the observations of such structures [16, 17] – even if there still is a debate if they are pseudocraters, small volcanoes or even modified impact craters [18, 19].

Terrestrial pingos in general: On the Earth, pingos are found in permafrost environments in Spitsbergen, Canada, Alaska, Greenland and Siberia. Collapsed paleopingos of England and Holland indicate previous permafrost conditions. Arctic pingos are laccolithic ice cumulates that may be exist together with polygonal wedge ice terrains. The ice-hearted, earth-covered pingo hill may reach over 50 metres in height and more than 500 m in diameter. Being periglacial, the pingo formation process is linked to the extended cold season and long-term ground ice accumulation without signs of glaciation.

Pingo characteristics and two basic types: While a small pingo may have regular shape of a rounded hill, large pingos display multiple depressions on their upper slopes and/or craters at their top due to a partial melting of the ice core. There may be tension summit fractures. Sandy and silty strata on the pingo slope may dip outward from the center, possibly due to the intrusive characteristics of the water body that freezes when reaching a level close to the pingo surface. An injection of fluid water can be considered to be analogous to small volcanic intrusion and dome formation.

Local pingo. Closed-system (hydrostatic) local pingos form in drained lakes or river channels where annually developing permafrost rises the former beds. Porous material at first draws water up over the permafrost, and then lets it freeze during the cold season resulting an ice core growth and an additional rise of the surface layers [cf. 20]. A growing hydrostatic pingo dome assumes the shape of drained circular pond to elongated channel.

Feeded pingo. Open-system (hydraulic) pingos are aquifer-feeded. In an extreme case, artesian water is pushed up to freeze close to the surface. Freezing adds mass to the expanding ice core and the pressure forces the ground up. Existing slope may increase the aquifer activity and the subsequent pingo growth. An aquifer-feeded pingo grows until the aquifer stops to work and it thus may reach a larger size than a closed-system pingo. The open-system pingos may have varying shapes depending on the geometry and changes in the aquifer system.

Pingo growth. The actual terrestrial pingo growth rate is debated. Estimations of pingo growth by processes related to water intrusion and frost heaving do vary. Assuming a growth rate of 2 cm/year it formally takes 2500 years for a pingo to grow 50 meters high. A growth rate of 1 cm/year gives 5000 years. A reasonable estimate is that a terrestrial pingo can grow a few centimetres per year and stand N times 1000 years (where N is a small whole number) before breaking down and collapsing. For a smaller pingo or for a pingo in not-so-frendly environment it may take decades or centuries only to reach the mature phase and to begin to decline.

Polygons and pingos on Mars: The Mars Phoenix lander studied a northern frost-wedge polygon terrain and discovered ice a few centimeters below the surface. In some favourable conditions this subsurface ice may have been more active and resulted in frost heave processes. Some high-resolution MOC and HiRISE (http://hirise.lpl.arizona.edu/results.php?keyword=Pingo&order=release_date&submit=Search) images show rather symmetrical dome-like structures on various locations on polygonal terrains on Mars. Of course, prosesses related to pseudocrater explosion, small-scale volcanism and even impact crater deformation have to be taken into the account in dome formation. If – and in environments where - these other formation mechanisms can be excluded we have a strong case to make a postulation of a pingo-like formation of small dome structures. The case is still stronger if the studied dome or dome group bears characteristics found in other structures that have been identified as pingos.

The area studied: We studied the central part of the Noachis Terra (36-47°S, 20-30°E; Figure 1) on the highlands to the west of the Hellas basin. This ancient terrain has large, eroded craters modified by fluvial processes. Inside a crater (45.98°S, 24.41°E) there are several small (diam. 20-120 m) mounds that are located within a surface unit which seems to have its origin from a channel that breaches the SW rim into the crater. The identified small hilly domes are strictly connected to that material which has apparently accumulated from the channel. They do not appear elsewhere on the crater floor.

The surrounding terrain, the actual dome environment and details of the structures bear strong evidences for pingo-like characteristics of the small hill studied. After detailed studies of these structures (unfortunately there are not any HiRISE images over them yet) we were able to exclude the other processes that are proposed for the formation of such small mounds: (A) They do not bear any signs of pseudocrater or hydrovolcanic explosion. (B) They have no evidences of being cinder cones, volcanic domes or small volcanic edifices. (C) The mounds do not have any indications of being modified impact craters. The environment - as a whole - has numerous signs of water activity in the past and the mounds have all the necessary characteristics that are needed to able to claim that they have developed under conditions and by the processes that are usually connected to pingos and their formation.

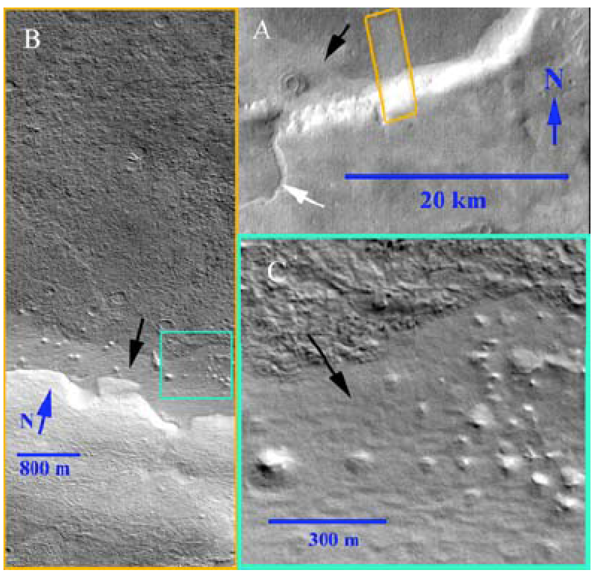

Figure 1. A) The impact crater has an inflow channel (white arrow) and associated deposits (black arrows; THEMIS I06466002). B) High-resolution MOC image (R1900276) shows that the deposit next to the crater rim is covered with small mounds. C) A close-up of the crater floor deposits shows the different textures of material units and that the darker rough unit is covered by the bright and smooth one.

There are still some uncertain aspects connected to these mounds that we propose to be pingo-like structures. We have not been able to identify if the structures were caused by a closed (hydrostatic) or open (hydraulic) system. If the pingo formation took place after the water flow was deceased, the pingos would be closed [20] ones and grown by local cycles of groundwater and permafrost activity. If the channel still offered additional water, the mounds may have formed as open system pingos feeded by aquifer-related water supply. The topography of the actual area of the pingo group favours the alternative that their growth has, at least partly, been supported by an amount of aquifer-feeded water supply. The closed-system alternative in their formation is favoured by their rather regular form and wide distribution within the unit they are located on.

Later loss of local water, permafrost aggradation and the formation of a sub-surface ice core could have deformed them and their upper elevations. Anyway, their existence and pingo-like characteristics seem to provide a clear proof of a small-scale water activity in the region. The channel-associated lowland deposit, the pingo-like features on it and some crater floor collapses nearby indicate that there have been and probably still are some amounts of water/ice/permafrost below the surface. The area should be of great interest to investigations by the HiRISE and SHARAD instruments on the MRO probe.

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