COMPARATIVE GEOSCIENTIFIC AND GEOMATIC ANALYSIS OF HYDROTHERMAL ZONES IN VOLCANIC TERRAIN ON EARTH AND MARS. M-C. Williamson[1], M. Germain[1], D. Lavoie[2], V.C. Gulick[3] [1]Canadian Space Agency, 6767 Route de l'Aéroport, St-Hubert, QC, J3Y 8Y9, Canada, [2]Geological Survey of Canada, 490 rue de la Couronne, Québec, QC, G1K 9A9 Canada, [3]NASA Ames Research Center, Moffett Field, CA 94035 U.S.A.

Introduction: Evidence for past life on Mars is most likely to be found within the preserved mineralized remains of subaerial, subaqueous, and shallow subsurface hydrothermal systems [1,2]. The most important targets of endogenic-driven hydrothermal activity identified so far occur in structurally complex, highly dissected and/or faulted volcanic terrain [3]. Recent discoveries of sedimentary structures and other features diagnostic of shallow water deposits and saline groundwater at Meridiani Planum [4] also raise the possibility of hydrothermal venting in areas where evaporites were deposited in volcanic terrain. The study of these geologically complex areas on Mars will require the careful, concurrent analysis of multiple databases [5,6].

Layers of geological, topographic, structural, mineralogical, geophysical and geochemical data integrated in Geographic Information Systems (GIS) enable this type of detailed classification and interpretation of complex volcanic terrains on Earth. We present results based on the study of (1) hydrothermal chimneys and alteration zones of Cretaceous age located in the Canadian Arctic Islands, Nunavut, and (2) Apollinaris Patera shield volcano on Mars that were obtained using an OpenGIS solution for terrestrial analogues and planetary databases.

Geology: On western Axel Heiberg Island, in the Canadian Arctic, erosional remnants of hydrothermal chimneys discovered at two localities consist of pyritiferous mounds that measure 2 to 5 m in cross-section and consist of a central vent and wide bands of whitish-yellow to ochre alteration (Fig. 1). The chimneys or alteration zones consistently occur in structurally complex areas where volcanic flows and/or sills intersect evaporite outliers at the periphery of the diapir. The salt domes were formed in an intracontinental rift basin when Upper Mississippian to Middle Pennsylvanian evaporite beds rose diapirically through the Mesozoic succession. Basaltic lava flows and pyroclastic deposits in this area were emplaced episodically, with peaks of intrusive and eruptive activity at 128 and 95 Ma, respectively [7]. Remarkably, cold springs are still active [8] and so there is growing evidence that hydrothermal systems constitute a long-lived, episodic feature of the rift basin.

The geological setting is broadly similar to that of conical siliceous mounds reported in the Paraná basin of southeastern Brazil [9] with the following notable exceptions: statiform, intrusive mafic igneous rocks are pervasive in the Sverdrup Basin, and although the chimneys are of a similar size to some of the Paraná structures, they are not as abundant.

Fig. 1 Field photograph taken at the head of East Fiord, western Axel Heiberg Island, showing the erosional remnant of a hydrothermal chimney exposed in anhydrite. The geological hammer at the base of the structure is 30 cm long.

In addition, the mineralogy of chimney deposits sampled at the North Agate Fiord locality includes Cu-Fe sulphides, suggesting smoker wall assemblages precipitated from hydrothermal vents in a submarine, rather than shallow subsurface (lake) or subaerial (geyser) environment [10]. The close association of chimneys with carbonate breccias at Junction diapir implies that an origin by hydrocarbon fluid venting or seepage cannot be discounted.

Given the hostile conditions for evolved multicellular carbon-based life on Mars, the best chances for finding past and even active life forms rely on bacterial chemosynthesis sustained through chemical emanations from hot near-surface springs to most likely sub-surface systems. Bacterial chemosynthesis has been recognized in the Cretaceous succession of Northern Canada with cold methane-oxidation as a likely process documented specifically on Ellef Ringes Island [11]. Initial petrographic examination of carbonate mounds associated with salt diapirs on Axel Heiberg Island documents the presence of cryptomicrobial peloidal laminae with associated early carbonate cement crusts that locally display a botryoidal fabric, moreover, serpulids worms can be locally abundant. All these elements are commonly found in modern and past chemosynthetic-based biological association, although the exact physico-chemical nature of the venting (hot or cold, CH_4 or H_2S emanations) has not yet been unequivocally determined.

Geomatics: A collaborative study is underway to integrate field observations with mineralogical, geochemical, structural, and geophysical databases for igneous rocks and evaporite structures on Axel Heiberg Island into a Geographic Information System (GIS). A strength of the GIS is to allow layers of information at any appropriate scale to be distinguished in order to resolve (1) the nature and extent of the volcanic plumbing system, and (2) the complex physical and relative age relationships between lava flows, intrusive rocks, chaotic breccias, and faults or collapse structures identified on a local scale at the periphery of salt domes. The GIS tool will be of great value to the proposed research and the scientific community, to extract from several databases the features and patterns relevant to hydrothermal systems on Earth and Mars.

Apollinaris Patera: Apollinaris Patera, located at the boundary between the northern plains and southern highlands of Mars (9°S, 186°E) consists of a partially preserved caldera that shows evidence of explosive and effusive volcanic activity [12]. The shield volcano spans approximately 180 km at its base, is surrounded by chaotic terrain, valleys and channels, and is classified as a top candidate for hydrothermal activity [1,3] (Fig.2). Both the study area on Axel Heiberg Island and Apollinaris Patera are characterized by a remarkably long-lived history of volcanism and tectonism, the prerequisites for mature, magmatically-driven hydrothermal systems to occur in rift settings. Some of the features interpreted from THEMIS images are of comparable scale to those observed in the Canadian Arctic: dissected terrain, prominent ridges and troughs, lava floods, and faults at regional scale. Detailed images of the western part of the volcano (Fig. 3) may reveal more subtle features such as collapse structures and igneous intrusions.

Conclusions: The spectacular exposures of chimneys, evaporite domes, and volcanic deposits on Axel Heiberg Island, Canadian Arctic Archipelago, provide a natural laboratory and terrestrial analogue to investigate the potential for hydrothermal activity in volcanic terrains on Mars. Preliminary results of comparative geoscientific and geomatic analysis for the study area and the Apollinaris Patera volcano suggest that this approach facilitates the classification of geological and structural features in these complex terrains.

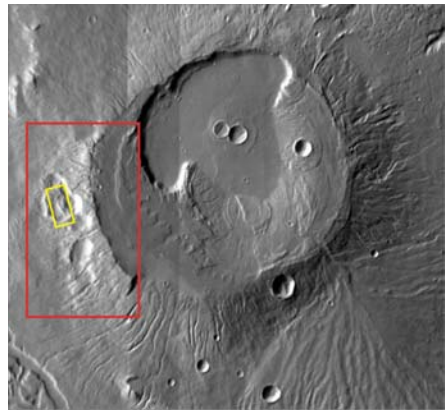

Fig. 2 THEMIS visible mosaic of Apollinaris Patera [13]. The box on the western side of the caldera illustrates the area of interest and footprint of Figure 3.

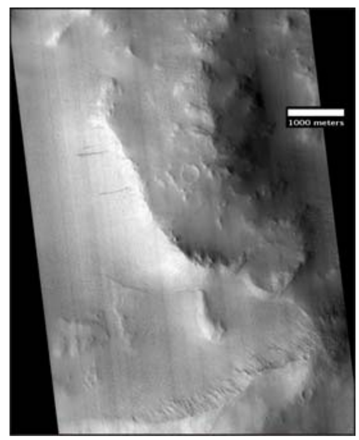

Fig. 3 HiRISE Image: PSP_0051_1715_red [14]

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