ICE CAVES ON MARS – A GOOD PLACE FOR LIVE AND TO LIFE!?: A. Pflitsch[1], Ch. Grebe[1], D. Holmgren[1] and M. Steinrücke[1], [1]Ruhr-University Bochum, Workgroup of Cave and Subway Climatology, Universitätsstr. 150, 44801 Bochum, Germany, andreas.pflitsch@rub.de

Introduction: Ice caves are defined as caves containing ice all year round [1], this also applies to other planets. Looking at the formation mechanisms of known and accessible ice caves this transmission is more difficult.

According to Lütscher [2] it can be distinguished between different types of ice in caves. These are divided in exogenetic (e.g. accumulations of snow at the cave entrance, firn or intrusive ice of warm glaciers) and endogenetic (infiltrated water that freezes to ice, hoar frost) ice. Ice caves occur either in permafrost areas or in temperate regions [3]. However ice caves occur predominantly in temperate areas above the 0°C-Isotherm.

In connection with the climatologic influences a more sophisticated description and accordingly a classification is possible. Important boundary criteria are the nature of the air flow and the amount of surface openings, as well as the morphology of the caves. Many formation criteria of ice caves do not apply to Mars because the atmospheric conditions differ enormously from those on earth. However the existence of ice caves containing water ice cannot be ruled out. This leads to interesting continuative thoughts regarding the existence of recent life and a possible future colonisation.

Theories about the formation of ice caves on earth: Especially Lütscher [2] was able to determine and generalise the basic factors for the formation and existence of durable cave ice by extensive research. These factors are:

1. Existence of H_20 in solid, liquid or gaseous appearance.
2. Existence of ice in a homothermal zone limited to permafrost areas ($T_{Altitude}< 0°C$).
3. Elevation of the ice cave under the 0°C-Isotherm: Development and outlasting of the ice because of thermal anomalies in the cave, morphology and structure of the cavity and its entrances. These anomalies are linked to the air circulation in the system.

Two most common types of ice caves:

Dynamic ice caves or temperature anomalies indicated by the chimney effect.

The principle of a dynamic ice cave is the so called chimney effect, which is based on a pressure difference between the air inside and outside of the cave. It also shows seasonal variability. If a cave has more than one natural entrance, pressure differences between the outer atmosphere and the air inside the cave lead to forced convection.

When in winter the outside temperature is deeper than the cave temperature, the cave air which is warmer than the outside air, flow out through the higher entrance [4]. At the lower entrance cold air flows in.

If the temperature of the cave walls is <0°C, this leads to freezing or resublimation of water in liquid or gaseous phase. The inflowing cold winter air in the lower part of the cave causes a gradual cooling of the rock surface and enhances built up of ice.

During summer on the other hand, when outside temperatures are above the cave temperature, the relatively cold and heavy air flows out through the lower entrance, while the warm air is being soaked in at the upper entrance. When the air reaches the deeper parts of the caves, it has cooled down, so that the cavities here are not warmed enough to trigger a decrease of ice.

Static ice caves or temperature anomalies indicated by a “cold air trap”.

If an ice cave has only one natural entrance which is situated in the upper or middle part of the cave, this cave can be a cold air trap.

Because of the density differences the air exchange of the outer atmosphere with the cave air is limited to a certain open phase which is defined by outside temperatures below cave temperatures ($T°_{OF} < T°_{cave}$).

The intensity of the air flow rises with decreasing outside temperatures. The specific heavier air flows into the cave and cools the rocks.

The warmer air is being replaced and flows out along the ceiling. In summer ($T°_{OF} > T°_{cave}$) the cooler air stays in the cold air trap and is warmed by the surrounding rocks.

If the ice melts simultaneously, the needed enthalpy of fusion inhibits additionally the warming of the cave. Stable temperature stratifications occur when deep temperatures are preserved over summer.

Ice caves on Mars: Basically both major types of ice caves that occur on earth cannot be ruled out for Mars, although the so far identified caves have completely different dimensions than ice caves on earth and there is no information about their morphology.

Anyhow there is no obvious reason why there could not exist caves with smaller openings or ramifications inside the known caves. As equivalent the Carlsbad Caverns can be mentioned where there is an almost completely separated system of circuits next to two bigger openings inside the cave. Therefore the cave comprises different microclimatic zones with different meteorological appearances – thermal and barometric driven.

The cave ice on Mars could either derive from very old large sources of ice which have not yet melted or sublimated or the ice is still formed today. The recent ice forming processes could either be triggered by melting process underneath the surface of Mars and corresponding drainage into the caves or by rising water which melts because of thermal processes inside the planet, rises into the caves and evaporates, sublimates or refreezes there. This can lead to the formation of ice lobes or to the formation of temporary ice crystals at the rock surface.

On the other hand also melting processes are possible either because of direct sunlight through the openings, inflowing warm air or thermal processes.

The melting of ice and its evaporation or sublimation would lead to a change of the cave atmosphere which – depending on size and morphology of the cave and the openings – would at least temporarily lead to a changing composition of the cave atmosphere compared to the atmosphere at the surface of Mars.

A higher humidity and vapour pressure, balanced temperatures and the absence of hard radiation would improve the chances of outlasting life inside the caves considerably.

Caves with large sources of water ice would simplify the colonisation of Mars considerably.

The different considerations are presented and discussed in the presentation.

References: [1] Bögli, A. (1978) Karsthydrographie und physische Speläologie, Berlin. [2] Lütscher, M. (2005) Processes in Ice Caves and their Significance for Paleoenvironmental Reconstructions. *Thèse université de Zürich, édition ISSKA, La Chaux-de-Fonds.* [3] Lütscher, M. and Jeannin, P.-Y. (2002) Une année d'enregistrements de températures á la glacière de Monlési / Ein Jahr Temperaturmessungen in der Glacière de Monlési (NE). *Stalactite 52(2), p. 27-29.* [4] Pflitsch, A.; Willes, M.; Horrocks, R. and Piasecky, J. (2010) About dynamic climatological processes of barometric cave systems in relation to the outside weather conditions and different cave structures. *ACTA CARSOLOGICA, Postojna, SL, 39/3, p. 449-462.*