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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.icarus.2012.02.027.

References

- Ansan, V. et al., 2011. Stratigraphy, mineralogy, and origin of layered deposits inside Terby crater, Mars. *Icarus* 211, 273–304.
- Arvidson, R.E. et al., 2003. Mantled and exhumed terrains in Terra Meridiani, Mars. *J. Geophys. Res.* 108 (E12), 8073.
- Bandfield, J.L., 2006. Extended surface exposures of granitoid compositions in Syrtis Major, Mars. *Geophys. Res. Lett.* 33, L06203.
- Bishop, J., Madejova, J., Komadel, P., Froschl, H., 2002. The influence of structural Fe, Al and Mg on the infrared OH bands in spectra of dioctahedral smectites. *Clay Miner.* 37, 607–616.
- Bishop, J.L. et al., 2009. Mineralogy of Juventae Chasma: Sulfates in the light-toned mounds, mafic minerals in the bedrock, and hydrated silica and hydroxylated ferric sulfate on the plateau. *J. Geophys. Res.* 114, E00D09.
- Blatt, H., Middleton, G., Murray, R., 1980. *Origin of Sedimentary Rocks*, second ed. Prentice Hall, New Jersey, 782pp.
- Brunskill, G.T., 1969. Fayetteville Green Lake, New York. II. Precipitation and Sedimentation of Calcite in a Meromictic Lake with Laminated Sediments. *Limnol. Oceanogr.* 14, 830–847.
- Buhler, P.B., Fassett, C.I., Head, J.W., Lamb, M.P., 2011. Evidence for paleolakes in Erythraea Fossa, Mars: Implications for an ancient hydrological cycle. *Icarus* 213, 104–115.
- Cabrol, N.A., Grin, E.A., 1999. Distribution, classification, and ages of martian impact crater lakes. *Icarus* 142, 160–172.
- Cabrol, N.A., Grin, E.A., 2001. The evolution of Lacustrine environments on Mars: Is Mars only hydrologically dormant? *Icarus* 149, 291–328.
- Christensen, P. et al., 2004. The thermal emission imaging system (THEMIS) for the Mars 2001 odyssey mission. *Space Sci. Rev.* 110, 85–130.
- Clark, R.N., King, T.V.V., Klejwa, M., Swayze, G., 1990. High spectral resolution reflectance spectroscopy of minerals. *J. Geophys. Res.* 95, 12653–12680.
- Clark, R.N. et al., 2007. USGS Digital Spectral Library splib06a. US Geol. Surv. Data, 231.
- Coakley, J.P., Rust, B.R., 1968. Sedimentation in an Arctic Lake. *J. Sediment. Petrol.* 38, 1290–1300.
- De Hon, R.A., 1992. Martian lake basins and Lacustrine plains. *Icarus* 56, 95–122.
- Dehouck, E., Mangold, N., Le Mouélic, S., Ansan, V., Poulet, F., 2010. Ismenius Cavus, Mars: A deep paleolake with phyllosilicate deposits. *Planet. Space Sci.* 58, 941–946.
- Di Achille, G., Hynke, B., 2010. Deltas and valley networks on Mars: Implications for a global hydrosphere. In: Cabrol, N., Grin, E. (Eds.), *Lakes on Mars*. Elsevier, Amsterdam, pp. 223–248.
- Dickson, J.L., Head, J.W., Marchant, D.R., 2010. Kilometer-thick ice accumulation and glaciation in the northern mid-latitudes of Mars: Evidence for crater-filling events in the Late Amazonian at Phlegra Montes. *Earth Planet. Sci. Lett.* 294, 332–342.
- Dickson, J.L., Head, J.W., Fassett, C.I., 2011. Ice accumulation and flow on Mars: Orientation trends and implications for climate in the Late Amazonian. *Lunar Planet. Sci.* XLIII, 1324. Abstract.
- Ehlmann, B. et al., 2008a. Clay minerals in delta deposits and organic preservation potential on Mars. *Nat. Geosci.* 1, 355–358.
- Ehlmann, B. et al., 2008b. Orbital identification of carbonate-bearing rocks on Mars. *Science* 322, 1828–1832.
- Ehlmann, B. et al., 2009. Identification of hydrated silicate minerals on Mars using MRO-CRISM: Geologic context near Nili Fossae and implications for aqueous alteration. *J. Geophys. Res.* 114, E00D08.
- Ehlmann, B.L. et al., 2011. Subsurface water and clay mineral formation during the early history of Mars. *Nature* 479, 53–60.
- Eugster, H.P., Hardie, L.A., 1975. Sedimentation in an Ancient Playa-Lake Complex: The Wilkins Peak Member of the Green River Formation of Wyoming. *Geol. Soc. Am. Bull.* 86, 319–334.
- Eugster, H.P., Hardie, L.A., 1978. *Saline lakes*. In: Lerman, A. (Ed.), *Lakes: Chemistry, Geology and Physics*. Springer-Verlag, New York, pp. 237–293.
- Fassett, C., Head, J., 2005. Fluvial sedimentary deposits on Mars: Ancient deltas in a crater lake in the Nili Fossae region. *Geophys. Res. Lett.* 32, L14201.
- Fassett, C.I., Head, J.W., 2008a. Valley network-fed, open-basin lakes on Mars: Distribution and implications for Noachian surface and subsurface hydrology. *Icarus* 198, 37–56.
- Fassett, C.I., Head, J.W., 2008b. The timing of martian valley network activity: Constraints from buffered crater counting. *Icarus* 195, 61–89.
- Forsythe, R.D., Zimelman, J.R., 1995. A case for ancient evaporite basins on Mars. *J. Geophys. Res.* 100, 5553–5563.
- Frost, R.L., Klopogge, J.T., Ding, Z., 2002. Near-infrared spectroscopic study of nontronites and ferruginous smectite. *Spectrochim. Acta Part A* 58, 1657–1668.
- Gaffey, S.J., 1987. Spectral reflectance of carbonate minerals in the visible and near infrared (0.35–2.55 μm): Anhydrous carbonate minerals. *J. Geophys. Res.* 92, 1429–1440.
- Gendrin, A. et al., 2005. Sulfates in martian layered terrains: The OMEGA/Mars Express view. *Science* 307, 1587–1591.
- Glotch, T.D., Bandfield, J.L., Tornabene, L.L., Jensen, H.B., Seelos, F.P., 2010. Distribution and formation of chlorides and phyllosilicates in Terra Sirenum, Mars. *Geophys. Res. Lett.* 37, L16202.
- Goldspiel, J.M., Squyres, S.W., 1991. Ancient aqueous sedimentation on Mars. *Icarus* 89, 392–410.
- Goudge, T.A., Head, J.W., Mustard, J.F., Fassett, C.I., 2011. Open-basin lakes on Mars: A study of mineralogy along a Paleolake Chain. *Lunar Planet. Sci.* XLII, 2131. Abstract.
- Greeley, R., Guest, J., 1987. Geologic map of the Eastern Equatorial region of Mars. US Geol. Surv. Misc. Invest. Ser., Map I-1802-B.
- Grin, E.A., Cabrol, N.A., 1997. Limnologic analysis of Gusev Crater Paleolake, Mars. *Icarus* 130, 461–474.
- Harrison, K.P., Grimm, R.E., 2005. Groundwater-controlled valley networks and the decline of surface runoff on early Mars. *J. Geophys. Res.* 110, E12S16.
- Harvey, R.P., Griswold, J., 2010. Burial, exhumation, metamorphism and other dastardly deeds exposed at the Hesperian/Noachian boundary in the Southern Nili Fossae region. *Lunar Planet. Sci.* XLI, 2045. Abstract.
- Hauber, E. et al., 2009. Sedimentary deposits in Xanthe Terra: Implications for the ancient climate of Mars. *Planet. Space Sci.* 57, 944–957.
- Hay, R.L., Goldman, S.G., Matthews, J.C., Lander, R.H., Duffin, M.E., Kyser, T.K., 1991. Clay mineral diagenesis in core KM-3 of Searles Lake, California. *Clays Clay Miner.* 39, 84–96.
- Head, J.W., Kreslavsky, M., Hiesinger, H., Ivanov, M., Pratt, S., Seibert, N., 1998. Oceans in the past history of Mars: Tests for their presence using Mars orbiter laser altimeter (MOLA) data. *Geophys. Res. Lett.* 25, 4401–4404.
- Head, J., Kreslavsky, M., Pratt, S., 2002. Northern lowlands of Mars: Evidence for widespread volcanic flooding and tectonic deformation in the Hesperian period. *J. Geophys. Res.* 107, E15004.
- Head, J., Mustard, J., Kreslavsky, M., Milliken, R., Marchant, D., 2003. Recent ice ages on Mars. *Nature* 426, 797–802.
- Head, J., Wilson, L., Dickson, J., Neukum, G., 2006. The Huygens–Hellas giant dike system on Mars: Implications for Late Noachian–Early Hesperian volcanic resurfacing and climatic evolution. *Geology* 34, 285–288.
- Head, J., Marchant, D., Kreslavsky, M., 2008. Formation of gullies on Mars: Link to recent climate history and insolation microenvironments implicate surface water flow origin. *Proc. Natl. Acad. Sci.* 105, 13258–13262.
- Head, J., Marchant, D., Dickson, J., Kress, A., Baker, D., 2010. Northern mid-latitude glaciation in the Late Amazonian period of Mars: Criteria for the recognition of debris-covered glacier and valley glacier landsystem deposits. *Earth Planet. Sci. Lett.* 294, 306–320.
- Hillier, S., 1993. Origin, diagenesis, and mineralogy of chlorite minerals in Devonian Lacustrine Mudrocks, Orcadian Basin, Scotland. *Clays Clay Miner.* 41, 240–259.
- Howard, A.D., Moore, J.M., Irwin, R.P., 2005. An intense terminal epoch of widespread fluvial activity on early Mars: 1. Valley network incision and associated deposits. *J. Geophys. Res.* 110, E12S14.
- Hughes, A.C.G. et al., 2011. A mineralogic and morphologic analysis of four new phyllosilicate-bearing martian fan deposits. *Lunar Planet. Sci.* XLII, 2301. Abstract.
- Hunt, G.R., Salisbury, J.W., 1971. Visible and near-infrared spectra of minerals and rocks: II. Carbonates. *Modern Geol.* 2, 23–30.
- Ingles, M., Anadon, P., 1991. Relationship of clay minerals to depositional environments in the non-marine Eocene Pontils Group, Se Ebro Basin (Spain). *J. Sediment. Petrol.* 61, 926–939.
- Irwin, R., Maxwell, T., Howard, A., Craddock, R., Leverington, D., 2002. A large Paleolake basin at the head of Ma'adim Vallis, Mars. *Science* 296, 2209–2212.
- Irwin, R., Howard, A., Craddock, R., Moore, J., 2005. An intense terminal epoch of widespread fluvial activity on early Mars: 2. Increased runoff and paleolake development. *J. Geophys. Res.* 110, E05S04.
- Irwin, R., Maxwell, T., Howard, A., 2007. Water budgets on early Mars: Empirical constraints from paleolake basin and watershed areas. In: 7th International Conference on Mars. Abstract 3400.
- Jones, B.F., 1986. Clay mineral diagenesis in lacustrine sediments. In: Mumpton, F. (Ed.), *Studies in Diagenesis*, US Geol. Surv. Bulletin 1578. US Geological Survey, Reston, pp. 291–300.
- Jones, B.F., Bowser, C.J., 1978. The mineralogy and related chemistry of lake sediments. In: Lerman, A. (Ed.), *Lakes: Chemistry, Geology and Physics*. Springer-Verlag, New York, pp. 179–235.
- Kelts, K., Hsu, K.J., 1978. Freshwater carbonate sedimentation. In: Lerman, A. (Ed.), *Lakes: Chemistry, Geology and Physics*. Springer-Verlag, New York, pp. 295–323.
- Kerber, L., Head, J.W., 2010. The age of the Medusae Fossae Formation: Evidence of Hesperian emplacement from crater morphology, stratigraphy, and ancient lava contacts. *Icarus* 206, 669–684.
- Kress, A., Head, J., 2008. Ring-mold craters in lineated valley fill and lobate debris aprons on Mars: Evidence for subsurface glacial ice. *Geophys. Res. Lett.* 35, L23206.