USING AN INEXPENSIVE DIGITAL CAMERA TO PHOTOGRAPH MARS-ANALOG MATERIALS AT THE SCALE OF THE MER MICROSCOPIC IMAGER, AND AT OTHER SCALES.

D. M. Burt[1] [1]Dept. of Geological Sciences, Arizona State Univ., Box 871404, Tempe, AZ 85287-1404 (dmburt@asu.edu).

Introduction: The high-resolution Microscopic Imagers (MI) on the Mars Exploration Rovers Spirit and Opportunity [1] have taken thousands of amazing close-up photos of Mars minerals and rocks with a field of view (FOV) of about 30 mm (1.2 in) square in a 1024 pixel-square image (i.e., a 1 megapixel image). This magnification is commonly quoted as 30 µm per pixel. Two frustrating limitations of the MI are first, that the photos are monochrome (gray-scale), and second, that the zoom and sample distance cannot be varied (i.e., each photo always shows the same-sized FOV). As might be expected, the depth of field (DOF) is also rather limited, and consequently all or part of any given image may be out of focus. Other than the gray-scale limitation, this makes the MI quite analogous to the traditional 10X hand lens of the field geologist, as intended.

For imaging Mars analog materials, the MI is also analogous to a consumer-level digital camera, except that digital imaging technology has advanced so far in the past few years that the consumer camera probably has far more capability than the MI (e.g., zoom lens, color capability, far greater pixel resolution, and, with a few simple add-ons, far more magnification capability). This fact allows many consumer-level cameras to be used to image possible Mars-analog materials (when images are deliberately cropped or downsampled and gray-scaled) in a manner analogous to the MI.

Camera Requirements: Most consumer level digital cameras can be used, some more easily than others. All such cameras have an LCD screen on the back of the camera and/or in an electronic viewfinder (EVF). Always use the LCD, rather than the optical viewfinder, for composing close-up images. Unfortunately, the LCD screen on the camera back may be difficult to see in direct sunlight, making an EVF a desirable feature.

Lens adaptor. The most important requirement for full usability is that the digital camera be capable of accepting add-on filters and lenses via a permanent threaded mount (as on the older Olympus C-2100UZ) or via the far more common optional lens adaptor that screws into the camera around the extending zoom lens. If this capability is lacking (as for many "clamshell-type" cameras), third-party lens adaptors may be available that screw into the tripod mount on the bottom of the camera. Otherwise, the macro capability built in to the camera may be adequate for fairly simple experiments, especially for higher resolution camera models.

Zoom lens. The greater the zoom range on the main camera lens, the greater the magnification that can be achieved, in general, so that I personally prefer to experiment with digicams having 10X or 12X zoom lenses. The 3X zoom range on most consumer-level cameras is pefectly adequate, however, and may even be preferable if the camera is to be hooked up to a telescope or microscope. In the latter case, an unusually tiny lens may be needed to prevent vignetting (a dark border around the image).

Image stabilization. If the camera is to be used hand-held in the field, vibration-absorbing image stabilization in the lens or camera body is very useful, especially for close-ups taken in low light. If this feature is lacking, it may be necessary to use the camera with a tripod or beanbag, and/or by "bouncing" the built-in flash (which may otherwise be unsuitable for extreme close-ups). Without a flash or image stabilization, using the camera's self-timer should minimize vibrations; using the burst mode (if available) may achieve the same result if the best photo of many is chosen.

Aperture-priority shooting mode. If available, this mode will allow the depth of field to be maximized, as the camera aperture is minimized (at maximum available F-stop). Most consumer digicams have far better depth of field than traditional 35 mm film cameras, in any case.

Techniques:

Camera alone. Many consumer-level digicams have quite good macro capabilities built-in. Just select the "flower" icon on the rotating mode wheel, or button, or menu, and begin experimenting. As mentioned above, aperture-priority shooting at maximum F-stop should maximize the depth of field. Caution: on most big-zoom digicams, the larger the zoom factor, the less the available light, the smaller the F-stop chosen by the camera, and the smaller the depth of field. Therefore, the best close-up photos may be achievable only at small zoom factors. Also, big zoom will increase focusable distance to the subject.

Camera plus close-up lens. If a screw-in lens adaptor is available for the camera, a greater magnification range and sometimes, a greater working distance is made possible by attaching close-up lenses. Use of step-up or step-down rings allows various diameter close-up lenses to be used with any camera. Expensive close-up lenses with multiple lens elements generally yield better results than simple, inexpensive, single-element close-up lenses (e.g., the +1,+2,+3 diopter sets commonly sold). Examples that I have used include the Olympus B-Macro and the Nikon 4T and 6T lenses, each of about +3 diopters. For greater magnification, two such close-up lenses can be combined (threaded into each other), although hand-holding the camera will then become more difficult. When using a close-up lens, you need not use the camera's macro or "flower" mode. You can use any camera mode (such as aperture-priority) in combination with the full magnification range of the zoom lens. At high zoom, focus is most easily achieved by moving the camera itself in and out until the image becomes sharp, rather than depending on the autofocus feature of the camera. For extreme magnification, avoid using +10 diopter close-up lenses. Better results are generally achievable via the "reverse macro" technique described next.

Reverse macro technique. Without using a microscope, the ultimate in sample magnification, up to 20X better than that of the Rover MI, involves use of an old 50 mm lens from a 35 mm single lens reflex camera. Such lenses are of very high optical quality, are very inexpensive to buy used, and generally have a 49 or 52 mm thread on the front. The lens is turned around and then threaded to the lens adaptor of the digicam via a cheap "male-to-male" reverse macro adaptor, available from most large camera stores, plus step-up or step-down rings (if needed). Prime lenses of F1.4 or less work best (less vignetting), but cheaper F1.8 lenses are perfectly adequate. In use, when the 50 mm lens is set at infinite focus and maximum aperture (minimum F stop), it becomes a high-quality +20 diopter close-up lens (the diopter rating of a close-up lens is 1000 mm over the focal length in mm). The 50 mm focal length assures you of several cm of working distance from the sample, but extremely limited depth of field, especially at big zoom. Use of a tripod is almost mandatory.

Afocal technique (with a microscope). As yet I have no personal experience with this technique, other than with telescopes, but I understand that it works the same with a microscope. Basically, the camera focus is set at infinity (whence the term "afocal") and the camera lens is placed, generally via an expensive adaptor, just above the eyepiece, where your eye would normally go. Focus is achieved with the focuser on the microscope. Unless the camera itself has a very tiny lens, extreme vignetting will result, as mentioned above. This pretty much limits the use of this technique (with microscopes) to some extremely tiny-lensed cameras made by Nikon, which is why I haven't tried it. (Telescope eyepieces can be considerably larger, allowing for afocal use of a wider range of digital cameras.) Try hand-holding the lens of your camera close to a microscope eyepiece before deciding if this techique might work for you.

Results. The following figures give two extreme examples of results obtained with one big-zoom consumer digicam (I've been using various high resolution consumer digicams since 1996, and image-stabilized big-zoom models since 2001). Other camera models should also work well.

Fig. 1. Hematitic concretion as non-linear "triplet" in Navajo Sandstone near Page, AZ. Handheld Panasonic FZ10 digicam in macro mode alone (at F5.6). Cropped FOV about 37 x 27 mm (index finger gives scale). Note excellent depth of field.

Fig. 2. Hematite- and caliche-coated iron spherules from Meteor Crater, AZ. Tripod-mounted Panasonic FZ10 digicam plus reverse macro coupled F1.4 Olympus 50 mm lens (+20 diopters). Aperture priority F8. Uncropped FOV about 4 x 3 mm. Note extremely limited depth of field.

Reference: [1] Herkenhoff, K. E. et al. (2003) *JGR, 108,* 8065, doi: 10.1029.2003JE002076.