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Use of Thermal Infrared Multispectral Scanner (TIMS) imagery to investigate upslope particle size controls on arid piedmont morphology

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Abstract

Geomorphic differences between slopes backing two distinct desert piedmont types provide a proxy indicator for the kind of landform developed at the corresponding mountain base. Here, the term 'bedrock pediment' describes subaerial bedrock platforms that emanate from a mountain base while 'alluvial slope' describes suballuvial bedrock platforms that extend from the mountain. Mountain slopes backing bedrock pediments have been demonstrated to be mantled by larger clast sizes than corresponding slopes backing alluvial slopes in the Phoenix region, Arizona, USA. The present research focuses on using the disparate particle sizes between slopes backing bedrock pediments and alluvial slopes as an indicator for the piedmont form developed at the mountain base, and uses high-resolution remotely sensed digital data as a medium for quantitative landform assessments. A gravel+bedrock versus soil index developed from airborne midinfrared multispectral imagery acquired by the Thermal Infrared Multispectral Scanner (TIMS) indicates the presence of slopes mantled with larger particle sizes versus slopes mantled with smaller particle sizes and greater soil coverage. Two test areas confirm the applicability of this method and further demonstrate the usefulness of high-resolution midinfrared multispectral imagery as a geomorphic tool in arid regions.

Keywords: Thermal Infrared Multispectral Scanner (TIMS); Pediment; Piedmont; Arizona

1. Introduction

This paper describes using imagery obtained by the NASA Thermal Infrared Multispectral Scanner (TIMS) to interpret particle size characteristics on mountain slopes above bedrock pediments and alluvial slopes in the Phoenix region, Arizona, USA, via a gravel+bedrock versus soil ratio. A bedrock pediment here refers to a low-angle subaerial, or mantled by only a thin layer of sediment, bedrock platform of low relief emanating from a mountain front. An alluvial slope (Bull, 1984) refers to a feature that exhibits a bedrock bench, but the bedrock is often buried under up to several meters of flood deposits (suballuvial). Surficial characteristics of alluvial slopes are often generally similar to those of alluvial fans-cone-shaped deposits of alluvium made by ephemeral mountain streams depositing sediment on piedmonts (Harvey, 1997). Applegarth (2004) found that mountain slopes

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above bedrock pediments in south-central Arizona tend to be mantled by larger particles than corresponding slopes backing alluvial slopes. Here we use slope particle size characteristics as an indicator of the presence of a bedrock pediment or alluvial slope developed at the mountain base.

In this study, remotely sensed midinfrared (also known as thermal infrared; here specifically the 8–14 μm wavelength range) imagery and laboratory-derived midinfrared rock spectra provide a means to differentiate slopes exhibiting greater exposures of bedrock–including both large clasts and outcrops–from slopes exhibiting greater soil coverage. A number of investigations using the TIMS instrument have been performed for geologic mapping purposes (Gillespie et al., 1984; Abrams et al., 1991; Ondrusek et al., 1993; Hook et al., 1994; Crowley and Hook, 1996; Morrissey, 1999; Ramsey and Fink, 1999; Buongiorno et al., 2002; Ramsey, 2002; Michalski et al., 2004). Studies of unconsolidated materials using TIMS have been comparatively few (Weitz and Farr, 1992; Ramsey et al., 1999; Stefanov, 2000). The TIMS was flown on various platforms from 1981 to 1996 when it was removed from service. A successor instrument, the MODIS/ASTER Simulator (MASTER), has increased wavelength and band coverage to serve as the airborne equivalent to the satellite-based Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) sensors in the visible, near infrared, shortwave infrared, and midinfrared wavelengths (Abrams, 2000; Hook et al., 2001). Fig. 1 illustrates the midinfrared band-passes for the TIMS, MASTER, and ASTER sensors.

With foothills and piedmonts typically occupied by (or targeted for) residential developments in semiarid to arid regions (Keller, 1992), providing a means to better interpret slope conditions and thus subsequent piedmont structure interests developers and planners as well as geomorphologists. By establishing a method to remotely assess piedmont type, a step is taken towards developing a model by which geomorphic surfaces may be efficiently determined on a variety of scales. Although the TIMS is now defunct, the methodology presented here should be readily applicable to midinfrared remote sensing data obtained from the currently operational MASTER and ASTER instruments.

2. Regional setting

The study areas are located in the Phoenix metropolitan region of south-central Arizona, USA (Fig. 2). Lithology was restricted to granitic and meta-granitic rocks in order to make comparisons between sites of similar rock types, and to mitigate lithology as a source of influence in corresponding results. Two discrete mountain ranges chosen exhibit a similar lithology yet dissimilar piedmont structure in order to test the applicability of the method. The White Tank Mountains (representing the alluvial slope area; Fig. 2) on the west boundary of the Phoenix metro area are a Tertiary metamorphic core complex with outcrops of Proterozoic crystalline rocks (Reynolds and DeWitt, 1991). The range's eastern flank consists of Cretaceous and Tertiary granitic plutons overprinted by Tertiary mylonites (Reynolds and DeWitt, 1991). Richard et al. (2000) mapped the range's southeastern flank as meta-granitic rocks overlain by Quaternary alluvium.

The McDowell Mountains (representing the bedrock pediment area; Fig. 2), located within the municipality of Scottsdale, AZ, were uplifted during Basin and Range extensional faulting around 18 Ma ago and consist of Early to Middle Proterozoic metasedimentary and metavolcanic rocks. The protolith assemblage was metamorphosed and deformed into a series of northeast-trending folds prior to the intrusion of Early to Middle Proterozoic granitic to dioritic rocks in the northern, northeastern, and southeastern portions of the range. Tertiary mafic to intermediate volcanic intrusives, lavas, and tuffs are located in the northern and southern portions of the range (Stefanov, 2000). Tertiary sedimentary rocks are also located to the south of the city of Fountain Hills (Skotnicki, 1995). According to

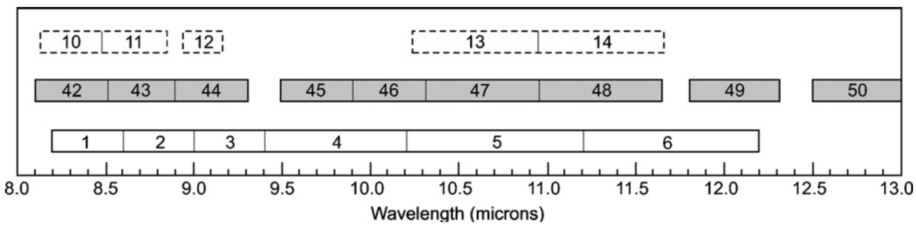

Fig. 1. Midinfrared band-passes for the TIMS (solid white rectangles), MASTER (solid gray rectangles) and ASTER (dashed white rectangles) sensors discussed in the text. Band numbers are indicated for each sensor.