1. Introduction

Layered deposits are widespread at all scales over the Martian surface, as shown since the first remote observations (Beyer & McEwen, 2005; Edgett, 2005; Edgett & Malin, 2002; Malin & Edgett, 2000; Tanaka, Scott, & Greeley, 1992; Thomas, Squyres, Herkenhoff, Howard, & Murray, 1992). Many authors have described some of these deposits sedimentary (Goldspiel & Squyres, 1991; Komatsu, Geissler, Strom, & Singer, 1993; Malin & Edgett, 2000; Nedell, Squyres, & Andersen, 1987; Salese et al., 2016; Squyres, 1989). Different scenarios and models have been proposed as an alternative to sedimentary origin of deposits, including multi-impact surges deposits (Knauth, Burt, & Wohletz, 2005), volcanic flows (McCollom & Hynek, 2005) and pyroclastic (Hynek, Phillips, & Arvidson, 2003; Kerber, Head, Madeleine, Forget, & Wilson, 2012). Some of the best-preserved layered deposits are located within impact crater basins (e.g. Becquerel, Firsoff, Crommelin, Vernal impact craters). The Meridiani Planum and Arabia Terra regions host many sites where intra-crater layered deposits have been observed (Andrews-Hanna, Zuber, Arvidson, & Wiseman, 2010; Edgett, 2005; Edgett & Malin, 2002; Lewis et al., 2008; Pondrelli et al., 2015; Rossi et al., 2008). Many models and scenarios have been proposed to explain the origin of these deposits, including wind deposition, volcanic flows and pyroclastic deposition, dust airfall, multi-impact surge deposits and groundwater upwelling (Andrews-Hanna et al., 2010; Andrews-Hanna & Lewis, 2011; Hynek et al., 2003; Kerber et al., 2012; Kite, Lewis, Lamb, Newman, & Richardson, 2013; Knauth et al., 2005; McCollom & Hynek, 2005; Michalski & Niles, 2012; Rossi et al., 2008). The Danielson Crater (Figure 1) is centered at coordinates 8°N 353°E; it contains one of the most preserved sedimentary filling of an impact basin on Mars, covering about the 75% of the crater’s floor. The well-bedded deposits consist of two interlayered materials, considered as single beds at the scale of available resolution: light-tone layers, which appear more resistant to weathering and erosion, and dark-toned layers, which appear to consist of recessive material (Figure 2(A)). We are aware that resolution may not allow the recognition of any layer below ~50 cm in thickness. The term ‘layer’ or ‘bed’ is often used in this work considering the data limits, as in other planetary works, although it may represent not a bed but a bedset. The goal of this study is to represent the lateral and vertical distribution of these layered deposits and to classify them into photo-stratigraphic units, using the photo-stratigraphic method (Sgavetti, 1992), to recognize the main structures and morphologies and provide a full detailed geological map (Main Map) of the area.

2. Methodology, data and map design

The mapping was performed using NASA Mars Reconnaissance Orbiter data, in particular from High-Resolution Imaging Science Experiment (HiRISE)
(McEwen et al., 2007) and Context Camera (CTX) (Malin et al., 2007) sensors. Images were processed using USGS ISIS 3 (Torson & Becker, 1997) and integrated in a GIS environment.

The geological map was compiled using MRO CTX images (~6 m/px resolution), which cover the entire study area. We choose to use a single data-set because this allows to avoid inconsistence during mapping process due to different resolutions and scales between different data-sets. Photographic properties of images were used to identify several photo-stratigraphic units, defined as the combination of image characteristics, such as photohorizons, which represent rock stratification, and photo-facies. The latter is the image expression of beds and/or packages of beds, as the combination of image characteristics (such as tonality and texture) and stratal geometry, including lateral continuity, shape of the erosional profile and bedding thickness and spacing (Sgavetti, 1992).

The HiRISE data-set (~25 cm/px resolution) covers about the 30% of the area; it was used for the detailed analyses of the geological properties and morphologies of the layered deposits. Stereo pairs of both HiRISE and CTX images were used to produce Digital Elevation

Figure 1. (A) CTX mosaic image of the Danielson Crater and its location on Mars. White boxes indicate the locations of Figure 2(B,C). The AA’ trace represents the location of the topographic profile shown in B. (B) Topographic profile across Danielson crater (continuous line) and inferred profile of the crater after a simple ballistic impact according to Garvin et al. (2003) (dashed line).
Models (DEM) using NASA-AMES Stereo Pipeline software (Broxton & Edwards, 2008; Moratto, Broxton, Beyer, Lundy, & Husmann, 2010). All DEMs were built by correcting images geometrically (bundle adjustment) and calibrated with High Resolution Stereo Camera DEM (Neukum & Jaumann, 2004) to obtain corrected elevations (referenced to MOLA aeroid) and used for geological and geomorphological analyses. A HiRISE DEM provided by USGS (DTEEC_002878_1880_002733_18901_U01) was used to perform detailed stratigraphic characterization of layered deposits. Strike and dip of beds were computed using the ArcGIS add-in LayerTools (Kneissl, van Gasselt, & Neukum, 2010): the use of this software could be affected by several error sources, such as limitations due to DEM resolution and/or interpolation of images’ holes, even human measurement errors. Nevertheless, results are coherent and provide the best possible dip and strike and thickness information based on available data. The main geological map was produced using ArcGIS and Adobe Illustrator and it is presented at a scale of 1:100,000 using equidistant cylindrical projection with center at 0 (IAU2000:49911). Cross-section was prepared by extracting elevations from MOLA data and manually drafting units on the underlying map.

3. The Danielson Crater

3.1. Geology of the impact crater

The Danielson crater (Figure 1(A)) is a complex impact crater, which shows an ellipsoidal shape of about 61 × 67 km; its surface extends for about 3000 km² with a maximum topographic depth of about 2.15 km from the rim. According to MOLA data, the deepest point of the crater floor reaches ∼−3450 m and the rim ∼−1400 m of absolute elevation. The deepest point measured does not correspond to the basement of the crater, due to the presence of the layered deposits (Figure 1(B)). Sedimentary infill thickness inside the crater basin can be estimated to ∼670 m, according
to Garvin equations (Garvin, Sakimoto, & Frawley, 2003; Garvin, Sakimoto, Frawley, & Schnetzler, 2002). The thickness measured implies that the original succession might have been ~2.5 km thick. The impact basin has not been dated directly, but according to Tanaka, Robbins, Fortezzo, Skinner, and Hare (2014), the crater could have been formed around ~4 Gyr (middle Noachian). Andrews-Hanna et al. (2010) and Carr and Head (2010) inferred the deposition of sedimentary deposits in Meridiani Planum and Arabia Terra between the late Noachian and the early Hesperian. Layered deposits form stairstepped geometries and cover about 75% of the crater floor. Along the inner edge walls, deposits onlap against the crater margin; this stratigraphic relation allows to infer that the sedimentary deposits were placed after the impact crater basin formation.

3.2. Photo-stratigraphic units

The geological map presented in this work shows several informal units, divided into two groups: the oldest Plateau units and the youngest Danielson formation. The first group includes two units which extend outside the crater basin; for simplification, we use the name assigned by other authors in previous geological map at global or regional scale (Edgett, 2005; Tanaka, Skinner, et al., 2014). The second group consists of the units recognized inside the basin and classified using the photo-stratigraphic unit and described in detail in this work.

3.2.1. Plateau units

3.2.1.1. Middle Noachian Highland Unit. The Middle Noachian Highland Unit (Figure 3(A)) was introduced by Edgett (2005) as a Scarp-form Unit and is mapped in the Geological Map of Mars by Tanaka, Skinner, et al. (2014). At a global scale, the unit consists of high-relief outcrops that extend hundreds to thousands of kilometers, commonly layered in crater walls. The unit has been estimated as hundreds of meters to more than a kilometer thick (Tanaka, Skinner, et al., 2014). At the regional scale, Edgett (2005) used the term Scarp-form due to the prominent scarp that forms along the western margin of North Sinus Meridiani. The latter morphology is recognizable outside impact craters, in plateau areas. Despite the strong dust cover, the unit is characterized by a medium to low albedo and by the presence of buried and partially buried craters, which is consistent with the old age assigned to these rocks.

3.2.1.2. Rim and Ejecta. The Rim and Ejecta Unit (Figure 3(B)) groups both the crater rim and ejecta deposits of Danielson Crater. They have been grouped Figure 3. Units in Danielson crater (north is up): Middle Noachian highlands Unit, or Scarp-form Unit (A) (CTX image P02_001744_1879_XI_07N008W); the eroded Rim and Ejecta Unit, both composed by original basement rocks reworked by the impact (B) (CTX images P07_003577_1878_XI_07N007W and B03_010697_1875_XI_07N007W); layered deposits describing Crater Unit 1 (c) (HiRISE image PSP_002733_1880_RED); deposits of Crater Unit 2 (D), less thick and with a different erosive style (HiRISE image PSP_002733_1880_RED); Crater Unit 3 in the south-central area of the crater (E) (HiRISE image PSP_002944_1880_RED), together with Crater Unit 2 is affected by several postdepositional structures in subhorizontal layers; the layered deposits of Crater Unit 4 (F) (HiRISE image ESP_027615_1880_RED) shows a chevron-like erosive profile of the beds together with the least bed thickness, sometimes unrecognizable. Unit 4 presents several yardangs along its extension; the inferred youngest deposit observable in the highest topographic area inside the crater (G) is Crater Unit 5, which possibly was the cap of the basin before the erosion. Different from other units, the Cap Rock Unit (H) is located in restricted areas on a topographic high in the eastern area and in the central area, and shows a layered and apparently more competent deposit overlying a more erodible material (HiRISE image PSP_002733_1880). The stratigraphic relationship between CUs and CRUa is unclear.
together to simplify the geological map, since they are not the main purpose of our work.

Rim and ejecta are formed by rocks of the same age of the basin, as they are re-placed material after the impact of the bolide that formed the Danielson Crater impact event. This material shows a highly eroded profile highlighted by the lack of a sharp edge of both rim and ejecta deposits. Ejecta deposits are smaller with respect to impact crater size, considering it therefore as remnant of an ancient impact, which is consistent with the hypothesized middle Noachian age of formation.

3.2.2. Danielson formation

The formation includes all the layered deposits within the Danielson Crater. According to the law of superposition, spatial arrangement and relative positions of beds (see cross-section on the map), the oldest layers are located in the northern area of Danielson Crater (Figure 2(B)) and the youngest ones are located in the southern area (Figure 2(C)).

At HiRISE scale (25 cm/px), the layered deposits, as noted by other authors (Cadieux & Kah, 2015; Stack, Grotzinger, & Milliken, 2013), appear to consist of two interbedded materials: a light-toned and more resistant to weathering and erosion and dark-toned and more erodible layers (Figure 2(A)). Due to selective erosion, light-toned layers are prominent and show definite morphologies while the darker toned units appear to be eroded at the point to be scarcely visible. These alternating layers produce a stai-step morphology which is particularly visible in the oldest part of the formation. Within the crater, the layered deposits are often faulted and affected by gentle and wide folds (with interlimb angle >150°), small folds associated to faults and tight folds (between ~30° and ~60° of interlimb angle). Despite discontinuities locally that appear to affect the layered deposits, layers are generally laterally and vertically continuous, and proceeding from the oldest unit to the youngest, a change in the morphology reflecting changes in the stratigraphic patterns (decrease of layer thickness and spacing, change in erosive profile, etc.) is observable. The Danielson Formation is subdivided into seven main units according to the method proposed by Sgavetti (1992), based on differences in image properties, erosion profile, bedding thickness and spacing. The transitions between the units appear to be always gradual and concordant. For simplification, we named the units as CU (Crater Unit) followed by a progressive number.

3.2.2.1. Crater Unit 1 (CU1). The CU1 (Figure 3(C)) is in the northern area of the impact crater and represents the oldest observable deposit on top of the basement. CU1 shows very regular bedding in thickness, albedo and erosional profile, generally laterally continuous with respect to younger units although displaying faults and gentle folds. Light-toned layers in this unit show a rounded and gentle erosional profile and a uniform tonality (Figure 3(C)). The texture is not easily recognizable, due to the presence of dust on the rock’s surface. The head of the beds reveals finely jagged edges. Dark-toned layers are only locally visible due to dust coverage. The layer couplets (light-toned and dark-toned) in CU1 are the thickest of the Danielson Formation, calculated between 8 and 22 m.

3.2.2.2. Crater Unit 2 (CU2)

3.2.2.2.1. Layered sub-unit (CU2a). The layered deposits that occupy the central part of the crater tend to gradually appear in a chevron-like shape (Figure 3(D)), showing a change in the erosional profile with respect to CU1. Bedding is subhorizontal (≤5°), shaping scattered mesa-like morphologies. Dark dust and debris accumulate in the depressions between the layers, covering part of the dark-toned layers with mega-ripples and dunes (e.g. Figure 5(D), white arrow), with heights between 1 m and 1.8 m. Light-toned layers, visible on subhorizontal dust-free surfaces, show polygonal patterns and subcircular-shaped depressions (Figure 5(D), black arrow, and Figure 5(E)). The size of polygons ranges from 0.5 to 25 m in width and shapes vary from square to irregular. Subcircular depressions range in length from 5 m to 80–100 m and widths from 2 m to 40 m, with an average size of about 30 m. The bottom is usually flat and shallow with a depth often up to 5 m. Layer couplets in this unit show thicknesses between 6 and 12 m.

3.2.2.2. South-flank of eastern relief (CU2b). CU2b sub-unit is in lateral continuity with the layered sub-unit. The sub-unit is confined at the foot of an eastern relief where part of the Cap Rock unit is emplaced (Figure 4). CU2b has a greater presence of aeolian deposits.
deposits and horizontal discontinuity of light-toned head of layers compared to CU2a.

3.2.2.3. Crater Unit 3 (CU3). Crater Unit 3 covers ∼18% of the Danielson Crater (Figure 3(E)). CU3 is characterized by a sharper erosive profile than CU2 and by thinner layering (layers couplet < ∼10 m thick). Despite the abundant dust cover which covers a large part of the Danielson Crater inner floor, CU3 layers show a good lateral continuity (for several kilometers) with few faults and folds. CU3 bed surfaces share the same morphologies described in CU2a.

3.2.2.4. Crater Unit 4 (CU4). The southern portion of Danielson Crater hosts very well-layered deposits (Figure 3(F)) that display possibly the thinnest bedding of the entire Danielson Formation (layers couplet < ∼5 m). The chevron-like erosive profile is very accentuated and jagged beds are visible in many locations (Figure 3(F)). The lateral continuity of layers is not easily recognizable due to the prominent heads of layers and dust coverage. Wind erosion is predominant in this area, as testified by iso-oriented NE/SW wind-sculpted mounds, interpreted as yardangs (Ward, 1979; Zimbelman & Griffin, 2010), showing a direction perpendicular to the layer’s strike. Widespread postdepositional structures (such as faults and folds) as in CU2 and CU3 are observable.

3.2.2.5. Crater Unit 5 (CU5). Crater Unit 5 deposits are located in the highest stratigraphic position of the Danielson formation and are found in the

Figure 5. Example of structural features in the layered deposits. Gentle folds (A) afflicting layers along the inner wall of the crater (highlighted by white dot lines) are possibly due to gravity accommodation. Faults are often associated with drag-folds (B), which allow to infer the block movement and suggest a certain plasticity of rocks (image centered at 8.08°N 353.18°E). Other folds (C) can be observed in the eastern area of the Danielson crater, suggesting a formation of slumps (image centered at 7.92°N 353.31°E). Stairstepped layered deposits in the southeastern area of the impact crater (D): the light-toned layer surface (black arrow) shows polygonal pattern, dark-toned layer (white arrow) is partially covered by postdepositional dunes and mega-ripples possibly composed by the same material (image centered at 7.68°N 353.21°E). (E) Subhorizontal light-toned layers show circular to subcircular depressions, several with a meandering channel (white dashed lines) following the local slope of the layer (image centered at 7.89°N, 353.24°E).
southernmost part of the geological map (Figure 3(G)). Layers display geometries and thicknesses very similar to CU2. Photohorizons are quite laterally continuous with respect to previous units and thicker (approximately ∼12–15 m on average) than those of the underlying units with higher albedo than CU4. A clear onlap relationship with the basement is visible.

3.2.2.6. Cap Rock Unit (CRU)

3.2.2.6.1. Layered sub-unit (CRUa). The layered sub-unit of CRU is found only in two outcrops in the central and eastern part of Danielson Crater, forming a couple of correspondent reliefs (Figure 3(H)). The CRU stratigraphic position is uncertain because the stratigraphic relation with adjacent units is unclear, due to apparent unconformities and/or dust cover. The CRUa unit consists of low-albedo, faintly layered and easily erodible material at the bottom, overlain by more resistant, well-layered high-albedo material, which forms the cap rock. In the central area of the Danielson Crater, the unit shows the largest polygonal patterns (up to 25 m in width), and it is affected by wind morphologies. The eastern outcrop is a subcircular relief, about 10 km in diameter and ∼300 m high, characterized by mesas, troughs and circular depressions (Baioni, Murana, & Sgavetti, 2012; Baioni, Murana, & Tramontana, 2014; Murana, 2012). The eastern relief shows anomalous stratigraphic relations: CU1 layers seems to be apparently cut off in NE flank (black arrow, Figure 4) instead of CU2b layers in SW flank, which seems in stratigraphic continuity with relief unit even if, in some areas, the gradual contact is not so clear by images (white arrow, Figure 4), suggesting the possible presence of unconformities.

3.2.2.6.2. Bright sub-unit (CRUb). Within the eastern relief, on the bottom of the depressions, bright coarse materials up to 300 m wide are observable. It is unclear whether these deposits are continuous with CRUa or not.

3.2.2.7. Recent aeolian deposits. A 155 km² large dune field is located in the middle of the Danielson Crater; these relatively recent loose deposits, possibly composed by fine to coarse sand, form barcanoid dunes (Hayward et al., 2007) 1.3 km wide on average. Slip faces face to the S-SW, which is consistent with the direction of the yardangs of CU4, suggesting a predominance of NE/SW winds.

3.3. Structural features

The oldest deposits (CU1, CU2 and CU3) of the Danielson Formation show pervasive fractures, faults and gentle folding. Normal and strike-slip faults (both dextral and sinistral) are present, about 74% of those observed are in the northeastern part of the layered formations and 26% are located in the southwestern side. The 65% of the longer fault traces (up to 850 m long) belong to strike-slip faults that are almost perpendicular (with angles between 76° and 88°) to the crater’s rim and follow the strata dip direction converging toward the crater’s center (Figure 5(B)). The NNW-SSE set of fractures appear to represent mostly normal faults – although in some cases the fault behavior is not clearly visible – whose displacement is in the order of several meters. Moreover, the change in layers dip and strike within some of the blocks close to the fault traces, also suggested by the ∼40% of the fault traces parallel to the crater’s rim, hint the listric geometry of the fault planes. The fault network isolates entire blocks of layered deposits, although this might also locally be related to alleged unconformities between layers, observed in many areas, where fault lines are not clearly visible. Along the fault line, mesoscale bed deformations are visible in several areas hinting for gentle strata deformation due to compression.

Kilometer-scale folding is observable mainly along the crater walls area, even if not always visible from images but highlighted by beds measurements and by three-dimensional perspective views (Figure 5(A)). Folds have different magnitudes and might have several origins, and they are distributed in CU1 and CU2 forming antiforms and synforms up to 3 km wide, with a clearly recognizable hinge zone, axial plane trace and limbs (up to ∼15° dip) resembling Earth-like monoclinal folds.

In other areas (e.g. the eastern area near the right flank of the anomalous relief), several asymmetric bent layered deposits are present, forming fold patterns different from the latter with subvertical plunging hinge, with steep limbs that form tight folds about 1 km wide which often overlap between them (Figure 5(C)).

3.4. Postdepositional sedimentary structures

Several post depositional sedimentary structures can be observed at HiRISE scale. In the dark-toned layers, mega-ripples and dunes fill the space between light-toned beds (Figure 5(D), white arrow).

The surface of the light-toned layers displays polygonal patterns due to the intersection of fractures with variable orientation. Polygonal surface (Figure 5(D)) appears flat at the scale of observation, without crisps or bulges. The polygon fractures propagate up to the jagged edges of layers, where polygonal-shaped fine blocks (Bruno & Ruban, 2017), with the average size of ∼1.2 m, detach and fall as debris. In both CU3 and CRUa, polygons are larger, reaching the decameter scale size and troughs are possibly deeper (highlighted by the projected shadow). In all of the other units, the
size of the polygons is generally at the meter scale and troughs seem to be shallower.

Within the subhorizontal light-toned layers, depressions of various shapes are widespread throughout the deposits; these morphologies are subcircular to irregular and are rimless and without ejecta (Figure 5 (E)). Subcircular depressions show short steep walls and low-albedo loose material covers the bottom, which is usually flat and shallow. The depressions could be isolated or coalescent, forming complex holes. On the same holes, sometimes, a straight or sinuous channel appears to source from the depression following the gentle slope of the light-toned bed in which is located the depression (Figure 5(E), black arrows).

4. Discussion and conclusions

The Danielson impact crater hosts one of the most preserved layered deposits of the whole area of Arabia Terra and Meridiani Planum. All the evidence observed in the study area are consistent with a formation of the layered deposits of evaporites, such as those proposed in several analogues successions of Arabia Terra and Meridiani Planum regions (Andrews-Hanna et al., 2010; Arvidson et al., 2003; Arvidson, Poulet, et al., 2006; Bibring et al., 2005; Carr & Head, 2010; Christensen et al., 2004; Golden, Ming, Morris, & Graff, 2008; Grifties, Arvidson, Poulet, & Gendrin, 2007; Klingelhoefer et al., 2004; McLennan et al., 2005; Metz et al., 2009; Pondrelli et al., 2015; Squyres et al., 2004; Wiseman et al., 2010).

In CU1, the jagged edges were formed possibly due to the erosion that produces the debris observable at the foot of each light-toned layer. Loose materials covering dark-toned layers may come from the same dark layers and being reworked by wind or come from outside the crater. In CRUa, there are younger wind morphologies possibly due to corrosion, interpreted as aeolian grooves (Bridges & Herkenhoff, 2002; Brookes, 2001). In CRUb, bright coarse deposits possibly are residual material due to punctual events of strong water flow or possibly rock debris. Another possibility concerns that the bright material is CRUa eroded by fluids.

Dune field shows very low albedo, very similar to other dune fields widespread on the Martian surface. The low albedo of dunes suggests a basaltic composition according to other studies, which implies the presence of olivine, pyroxene and hydrated minerals (Tirsch, Jaumann, Pacifici, & Poulet, 2011). Proposed scenarios for the origin of these materials are related to impacts or volcanic eruptions (Edgett & Lancaster, 1993) or provenance from the erosion inside impact craters of local outcrops possibly related to sedimentary or volcanoclastic origin (Fenton, 2005; Tirsch et al., 2011).

The presence of both ductile and brittle deformations, such as folding in the layered deposits parallel to the rim, strike-slip faulting perpendicular to the rim and normal faulting (Figure 5), might reflect passive features due to accommodation and sliding under gravity along the steep walls of the impact crater, forming what on Earth is known as gravitative tectonism (Dramis, 1984; Engelen, 1963; Goguel, 1978; Radbruch-Hall, 1978; Sorriso-Valvo, 1984). The drag-folds seem to show a vertical hinge, but the relation with faulting is unclear suggesting the relation of these structures to a larger scale deformation. In the eastern relief, the relatively good preservation state of the folded layers suggests slow mass movement of only partly consolidated high-viscosity materials. The geometries of structures suggest a process that would imply underwater mass wasting of plastic rocks, known as slump deposits (Decima & Wezel, 1971; Parea & Ricci Lucchi, 1972; Ricci Lucchi, 1973; Schreiber, Friedman, Decima, & Schreiber, 1976), which is also consistent with the location close to the relief of the crater margin.

With regard to postdepositional sedimentary structures, the relationship between dark-toned layers and wind features is not clear; mega-ripples possibly are reworked eroded dark-toned layered deposits sediments or instead they can be allochthonous material carried by the wind. Polygonal patterns on top of light-toned beds show strong similarities with polygonal cracks (Figure 5(D), black arrows). Polygonal morphologies are widespread on Mars and have been related to mineral dehydration and desiccation processes (Chavdarian & Sumner, 2006, 2011; El-Maarry et al., 2014) or thermal contraction polygons related to ice-, sand- and composite-wedge mechanisms (Levy, Head, & Marchant, 2009; Levy, Marchant, & Head, 2010). Subcircular depressions show scales, morphologies and features comparable to karsts morphologies, either created by the corrosive and dissolutive action of water or by thermokarst processes, hypothesized in many areas of Mars, including Meridiani Planum, by other authors (Baioni & Sgavetti, 2013; Balme & Gallagher, 2009; Grindrod & Balme, 2010; Jackson, Adams, Dooley, Gillespie, & Montgomery, 2011; Soare, Osinski, & Roehm, 2008; Warner, Gupta, Kim, Lin, & Muller, 2010). In particular, shape and the presence of straight-to-sinuous channels, sourcing from the edge of the pans, suggest an analogy with panholes or solution pans (Ford & Williams, 2007) or thermokarst ponds (Grosse et al., 2008; Soare et al., 2008). These landforms have been recognized and described by other authors (Baioni & Sgavetti, 2013; Baioni, Murana, & Hajna, 2014; Baioni, Murana, & Tramontana, 2014; Soare et al., 2008; Warner et al., 2010), with several interpretations about their origin (e.g. karst, thermokarst, aeolian processes, volcanism, impact processes).
The mineralogical signature of the light-toned layered deposits of Meridiani Planum and Arabia Terra was inferred by many authors using spectral data (Andrews-Hanna et al., 2010; Arvidson, Squyres, et al., 2006; Michalski et al., 2013; Wiseman et al., 2008; Wiseman et al., 2010). In particular, Wiseman et al. (2010) described the nearby deposits of North Sinus Meridiani, with the support of CRISM and OMEGA (Bibring et al., 2004) data and recognized spectral signatures belonging to Fe/Mg smectites, monohydrated and polyhydrated sulfates widespread throughout the region. In addition to previous observations, Pondrelli et al. (2015) in Firsoff crater and nearby craters (southwestward our study area) showed spectral signatures of Mg-rich polyhydrated sulfates, detected on the light-toned surface of layered deposits.

The geometry of layers into the Danielson Crater appears to drape and onlap the basement, suggesting settling as main depositional process; this geometry is consistent with evaporitic precipitation, such as in salt lakes, sabkha or saline ponds (Forsythe & Zimbelman, 1995; Lowenstein & Hardie, 1985; Mikucki, Lyons, Hawes, Lanoil, & Doran, 2010; Ori & Marinangeli, 2002). Moreover, the layers lack cross-bedding geometries, often clearly visible at the HiRISE scale (Pondrelli et al., 2015). Other works interpreted these layered deposits as the results of mixed action of climate changes. The lack of a drainage system around the impact crater and old channels, terraces and deltas in correspondence of the inner rim of the crater, rule out the possibility of an external source area feeding the basing through surficial transport processes. We suggest that the water sourced as groundwater upwelling from local to regional subsurface aquifers, in agreement with several authors (Andrews-Hanna et al., 2010; Andrews-Hanna & Lewis, 2011; Rossi et al., 2008). Groundwater upwelling might have flooded the Danielson Crater following the rising of the water table possibly through the fractures caused by the impact crater formation. The groundwater upwelling scenario is still uncertain; further work is needed to better constrain the processes and the controls that led to the formation of these deposits.

**Software**

The geological map was compiled using ArcGIS for mapping and Adobe Illustrator for final layout. All images were downloaded from Mars Orbital Data Explorer (http://ode.rsl.wustl.edu/mars/) and from HiRISE Arizona IPL website (http://hirise.lpl.arizona.edu/). USGS ISIS 3 was used to process raw images and NASA-AMES Stereo Pipeline was used to build DEMs using stereo pairs.

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**Disclosure statement**

No potential conflict of interest was reported by the author.

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