A Sponge/Coral-like specimen at Gale Crater, Mars? Results from Deep Learning, Cluster Analysis, and Multi-Dimensional Scaling using Orange Data Mining Image Analytics

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Abstract

Unusual branched specimens resembling a sponge or coral-like organism have been photographed in Gale Crater on sol 3396. The most complete specimen was approximately 1.3 cm across and appeared to comprise a series of branched 'tubes' attached to the substratum at a single point. Whether these specimens are biogenic or abiogenic is unclear. Hence, Orange Data Mining Image Analytics software was employed to make comparisons with terrestrial analogues including living algae, lichens, and living and fossil sponges and corals and abiogenic analogues such as fulgurite, selenite, and stalagmites. Image analytics, involving use of a pre-trained deep convolutional neural network, hierarchical cluster analysis, and multi-dimensional scaling, suggested little morphological similarity with the abiogenic specimens included but a significant similarity to living and fossil sponges. The analyses confirm previous subjective interpretations that the Martian form closely resembles a sponge-like organism.

Key words: Curiosity rover, Gale crater, Terrestrial analogue, Orange Data Mining Image Analytics

1. Introduction

Unusual branched specimens resembling a sponge or coral-like organism were described from Gale crater, Mars and photographed by the Curiosity rover 'Mars Hand Lens Imager' (MAHLI) on sol 3396 (Armstrong 2022). At least seven individual specimens were observed attached to a sandy substratum with frequent 'ripple marks' suggesting ancient water movement (Figs 1 and 2) (Joseph et al 2022a). The most complete specimen (Fig 2b) is approximately 1.3 cm across and consists of a series of interconnected 'flask-shaped' branches, possibly tubular, attached to the sediment. The 'tube-like' processes are narrower at the base before expanding and terminating in a rounded or flattened tip. In some of the images, the surface of the 'tubes' appear to have a reticulate texture, punctuated by possible holes or pores and to have evidence of holes at the tips of the tubes (Armstrong 2022).

In the original paper (Armstrong 2022), these specimens were interpreted subjectively as a type of sponge or coral but various explanations are possible (Armstrong 2022; Joseph et al. 2022a). Additional explanations include an abiogenic origin such as the precipitation of minerals from flowing water analogous to stalagmites, 'fulgurite' that forms when lightning strikes and fuse sand particles together to form complex shapes, or 'selenite' in the form of 'gypsum flowers' (see also Armstrong et al. 2023). Moreover, in addition to a sponge or coral, the specimen could be another type of branched organism such as an alga or lichen.

One method of establishing the possible affinity of a Martian specimen is to compare it to various terrestrial specimens which have a similar morphology. This has been achieved in previous

studies either by direct comparison of morphological features (Joseph et al. 2020a,b; 2021a,b,c; Armstrong 2022) or by employing a quantitative method of comparison based on fractal analysis (Bianciardi et al. 2015, 2021; Rizzo et al. 2021) or principal components analysis (PCA) (Armstrong 2021a,b, 2022). Subjective assessments lack objectivity (Rizzo et al. 2017) while PCA is sensitive to the selection of metrics used for the comparison and to the inevitably small sample sizes available which can lead to problems of statistical inference (Prajapati et al. 2010, Armstrong 2021a,b).

An alternative method is to use Orange Data Mining Image Analytics software to analyze the images. This software, which is free and designed for novel and experienced users and capable of analysing available data largely without human intervention via a pre-trained deep convolutional neural network (Godec et al. 2019). Hence, one of the objectives of this article was to examine the potential usefulness of the software in evaluating Martian specimens and comparing them to terrestrial analogues.

Fig 1. The location in Gale crater where the sponge-coral-like specimens were observed: (a) General view of terrain (3396ML1015330101205206C00_DXXX), (b) View of flat sediments with possible ripple marks and scattered small rocks(1029985) (NASA/JPL – Caltech)

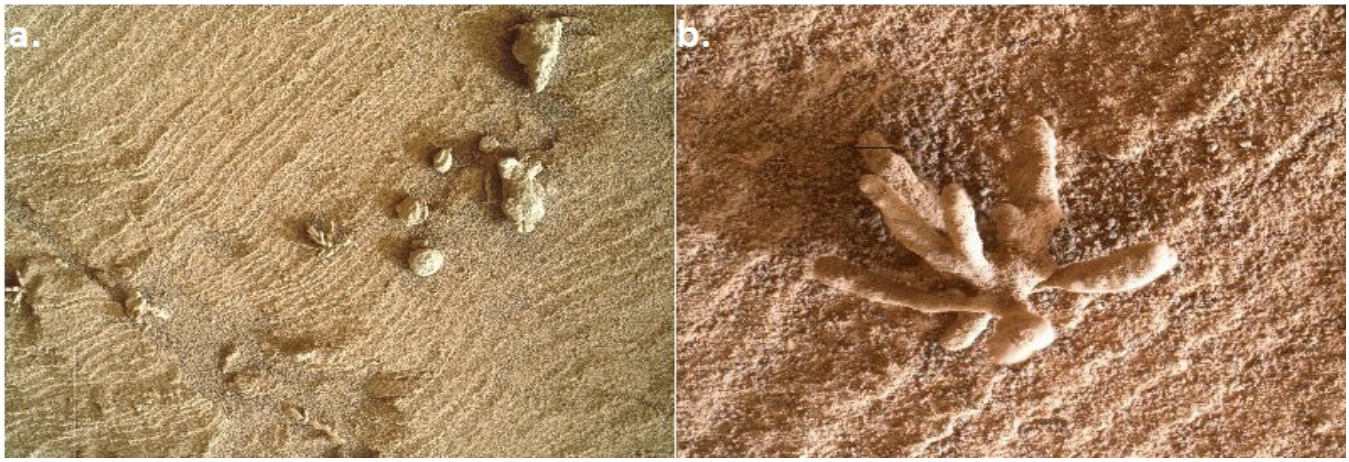

Fig 2. The sponge-coral-like specimens: (a) View of the site showing various specimens (b) The best preserved specimen (Both MAHLI; 3396MH0001760011201019C00_DXXX). Note in (b) the tubular branches attached by a single point to the substratum, the variation in width of the tubes, and the slightly rounded or flattened tips (NASA/JPL – Caltech)

Table 1. Sources of the images used in the analysis.

Image code	*Organism*	*Species*	*Source*
Martian -	-	`	NASA/JPL – Caltech
A1	Alga	*Dasycladus sp.*	(naturalmediterraneo.com/forum/topic.asp ?TOPIC_ID=97984)
A2	Alga	*Dasycladus sp.*	(galerie.sincearasy.cz; Jan kaštovský)
L1	Lichen	*Evernia prunastri*	www.britishlichens.co.uk; Mike Sutcliffe
L2	Lichen	*Ramalina siliquosa*	www.britishlichens.co.uk; Mike Sutcliffe
FS1	Fossil sponge	*Perindella* sp.	M. Land (www.sciencephoto.com/media/171539/ view/fossil-sponge)
FS2	Fossil sponge	*Hazella delicatula*	Briggs et al. 1994, Smithsonian books, P73
FS3	Fossil sponge	*Vauxia* sp.	Briggs et al. 1994, Smithsonian books, P80
S1	Sponge	?	Digital Atlas of Ancient Life
S2	Sponge	?	Digital Atlas of Ancient Life (www.digitalatlasofancientlife.org/learn/porifera)
S3	Sponge	?	(www.sciencenews.org/article/possible-ancestor -sponges-found
S4	Sponge	'Sea orange'	Torsten Thomas, UNSW Science
FC	Fossil coral	?	M.A. Wilson, Geology Dept. Wooster College
C	Coral	*Syringopara* sp.	M.A. Wilson, Geology Dept, Wooster College
FUL1	Fulgurite	-	www.ripleys.com
FUL2	Fulgurite	-	Oxford University of Natural History
FUL3	Fulgurite	-	www.shutterstock.com
GYP1	Selenite	-	www.rockngem.com
GYP2	Selenite	-	www.flickr.com/photos/jessicab_67/753646715
STAL1	Stalagmite	-	www.sciencephoto.com; Millard H Sharp
STAL2	Stalagmite	-	Chris Howes/Wildplaces Photography/Alamy

2. Methods

2.1 Images

The image of the most complete Martian specimen observed on sol 3396 (Fig 2b) was compared with a selected group of images of various terrestrial living organisms, including algae, lichens, sponges, and corals, various fossil sponges and corals, and various abiogenic features including examples of fulgurite, selenite ('gypsum flowers'), and stalagmites (Table 1). The biological organisms include two algae (*Dasycladus* sp.) (Huang & Lu 2006), two lichens (*Evernia prunastri*, *Ramalina siliquosa*), two corals, including a fossil coral, and seven sponges including three fossil sponges. Using Image analysis software, the images were analysed as follows (Fig 3): (a) the original image with no processing, (b) the original image with detection of the edges of visible objects ('edge detection'), (c) the image converted to binary and the outlines of the objects obtained ('outlined'), and (d) the image converted to binary and its 'skeleton' obtained and which reflects branching patterns ('skeletonised'). The sources of the various images used in the analysis are given in Table 1.

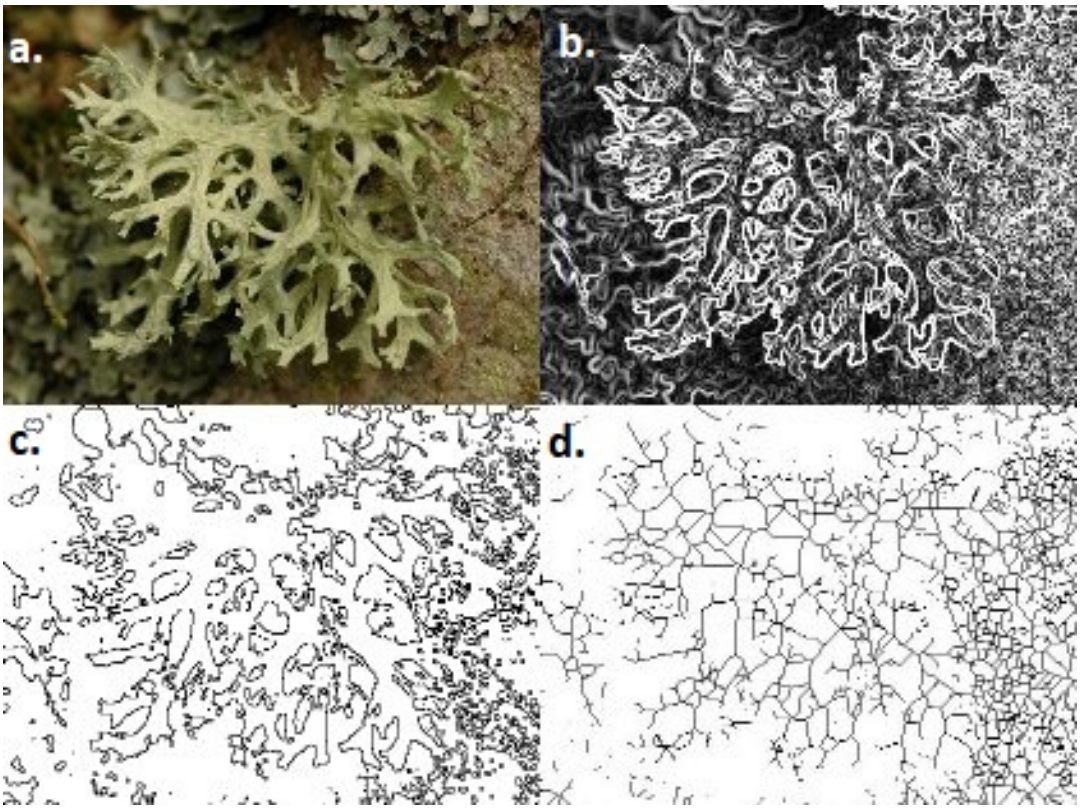

Figure 3. Examples of the processing applied to the image of the lichen *Evernia prunastri* (specimen L1) (British Lichen Society, Mike Sutcliffe): (a) Original image, (b) With edge detection, (c) Outlined, and (d) Skeletonised.

2.2 Analysis

Images were analyzed using Orange data mining software (version 3.35.0) with additional ImageAnalytics (version 0.11.0) (Demšar et al. 2013, Godec et al. 2019) and available as a free download (http://orangedatamining.com). The workflow of the analysis is shown schematically in Fig 4. Each set of images was imported as PNG files and then embedded using the Google Inception V3 deep convolutional neural network pre-trained on ImageNet. Embedding generated 2048 column vectors from each image representing morphology, color, and texture (Szegady et al. 2016). This is the software default method and although other methods are available, their relative utility in the analysis of Martian images has not yet been evaluated.

The columns were normalized to ensure equal weighting of all 2048 vectors. Distances were then computed among the vector columns using the Cosine metric which is known to work well with image vectors and reflects the degree of similarity among images. The resulting 'distance matrix' was inputed to: (1) Hierarchical clustering' (HC) (using the default 'Ward' method) and which results in a dendrogram obtained from the calculated distances and (2) Multi-Dimensional Scaling (MDS) which displays the relationships between the images spatially in 2D or 3D, the distances between images reflecting their degree of similarity. MDS is analogous to PCA which has been used previously to study the relationships between Martian specimens and terrestrial analogues (Armstrong 2021a,b, 2023) but has the advantage of being able to use a wider range of methods to assess similarity. In addition, MDS provides several further insights into the similarities among the images, first, by indicating which pairs

of images are likely to exhibit affinities (by joining them with a line) and second, by the size of the round symbol representing the image, larger sizes indicating less confidence in the location of the symbol in the 2D approximation of the multi-dimensional model.

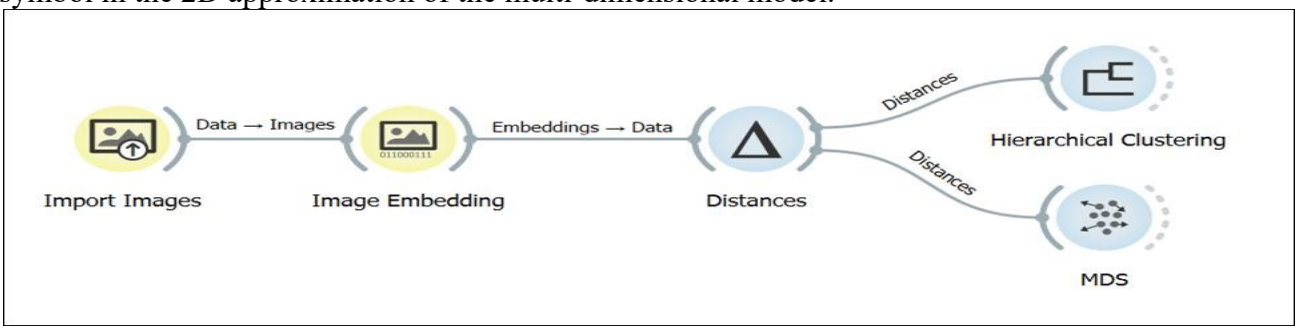

Fig 4. Workflow for the analysis carried out using Orange data mining image analytics software.

3. Results

Table 2. The image metadata and the first three (*n0, n1, n2*) only of the 2048 columns (*n0 – n2047*) of vectors extracted from each image (A = Alga, C = Coral, FC = Fossil coral, FS = Fossil sponge, FUL = Fulgurite, GYP = Selenite ('Gypsum flowers'), L = Lichen, MS = Martian specimen, S = Sponge, STAL = Stalagmite

Image code	*Size*	*Width*	*Height*	*n0*	*n1*	*n2*
A1	1220177	800	562	0.258851	0.0771948	0
A2	849490	800	600	0.0617988	0.0100128	0.0314792
C	399231	528	466	0.512109	0.0219827	0.041687
FC	390916	664	596	0.34118	0	0.566622
FS1	1049368	692	568	0.350193	0.103447	0.0261411
FS2	426965	449	509	0.469339	0.198849	0.0963438
FS3	3907171	1166	1877	0.425608	0.20169	0.00430781
FUL1	421730	674	674	0.166717	0.090549	0.529364
FUL2	342633	800	532	0.411062	0.0232642	0.183601
FUL3	477126	503	758	0.187794	0.352699	0.454304
GYP1	823529	696	583	0.154882	0.128767	0.0506506
GYP2	1161743	774	590	0.35791	0.097727	0.0261954
L1	665759	750	500	0.0725847	0.102848	0.350894
L2	346832	400	500	0.0382885	0.629041	0.0294469
MS	917537	703	575	0.231727	0.141571	0.0254947
S1	420630	634	474	0.454813	0.0406547	0.0461058
S2	284011	779	437	1.12433	0.126468	0.112887
S3	359736	643	460	0.346168	0.000904069	0.113401
S4	421190	553	522	0.145855	0.0725364	0.185965
STAL1	1041564	800	527	0.606527	0.133671	0.038654
STAL2	811026	609	573	0.037741	0.0854663	0.144312

Table 2 shows the image 'metadata' and the first three only (n0, n1, n2) of the 2048 columns of vectors extracted from each of the original images without processing. These data are used to construct a 'distance matrix' which is computed from the 2048 columns of vectors extracted from each image and shown in Table 3. Based on this matrix, the results of the HC analysis of the original images is shown in Fig 5. The dendrogram shows close clustering between the Martian specimen and a group of biological specimens, viz. two living sponges (S1,S4), a fossil sponge (FS1), and an alga (A2). By contrast, there is no clustering with the abiogenic features analyzed including examples of fulgurite, selenite, or stalagmites. The results of the MDS of the original specimens are shown in Fig 6 and, based on distance show that the closest established link with the Martian specimen is the sponge (S1). More remote links are also suggested first, with the fossil sponge (FS1) and more remote links with the branched lichen specimen (L1) and the alga A2.

The result of image processing is shown in Table 4. Processing of the image reduces the number of possible analogues but all processing methods continue to identity a living or fossil sponge as the closest match to the Martian specimen. More remote links are also shown with the alga (A1) in two of the analyses ('edge detection' and 'skeletonised' images). Only in one analysis (binary outlines) is there a match to an abiogenic specimen (FUL2) (binary,'outlined').

Table 3. The 'distance matrix' computed from the 2048 column vectors extracted from each image (A = Alga, C = Coral, FC = Fossil coral, FS = Fossil sponge, FUL = Fulgurite, GYP = Selenite ('Gypsum flowers'), L = Lichen, S = Sponge, STAL = Stalagmite

	A1	A2	C	FC	FS1	FS2	FS3	FUL1	FUL2	FUL3	GYP1	GYP2	L1	L2	Martian specimen	S1	S2	S3	S4	STAL1	STAL2
A1		0.301	0.450	0.527	0.338	0.551	0.507	0.452	0.483	0.531	0.501	0.426	0.411	0.416	0.464	0.402	0.476	0.539	0.404	0.469	0.556
A2	0.301		0.325	0.428	0.240	0.493	0.419	0.320	0.388	0.427	0.366	0.338	0.252	0.334	0.347	0.347	0.377	0.512	0.272	0.399	0.454
C	0.450	0.325		0.406	0.283	0.508	0.459	0.355	0.405	0.440	0.296	0.406	0.317	0.394	0.355	0.339	0.415	0.300	0.332	0.341	0.367
FC	0.527	0.428	0.406		0.402	0.509	0.440	0.426	0.444	0.351	0.468	0.470	0.442	0.424	0.427	0.413	0.404	0.449	0.505	0.404	0.421
FS1	0.338	0.240	0.283	0.402		0.535	0.406	0.327	0.351	0.396	0.402	0.357	0.249	0.319	0.264	0.278	0.350	0.475	0.246	0.409	0.442
FS2	0.551	0.493	0.508	0.509	0.535		0.399	0.467	0.492	0.490	0.521	0.578	0.549	0.538	0.454	0.486	0.523	0.587	0.569	0.494	0.501
FS3	0.507	0.419	0.459	0.440	0.406	0.399		0.469	0.515	0.459	0.492	0.515	0.469	0.453	0.390	0.387	0.429	0.554	0.502	0.433	0.482
FUL1	0.452	0.320	0.355	0.426	0.327	0.467	0.469		0.263	0.352	0.414	0.410	0.377	0.374	0.396	0.397	0.334	0.438	0.368	0.438	0.445
FUL2	0.483	0.388	0.405	0.444	0.351	0.492	0.515	0.263		0.344	0.437	0.458	0.380	0.431	0.432	0.406	0.313	0.517	0.403	0.418	0.453
FUL3	0.531	0.427	0.440	0.351	0.396	0.490	0.459	0.352	0.344		0.499	0.435	0.406	0.399	0.409	0.427	0.323	0.551	0.488	0.487	0.490
GYP1	0.501	0.366	0.296	0.468	0.402	0.521	0.492	0.414	0.437	0.499		0.377	0.337	0.406	0.385	0.427	0.463	0.418	0.437	0.284	0.252
GYP2	0.426	0.338	0.406	0.470	0.357	0.578	0.515	0.410	0.458	0.435	0.377		0.335	0.314	0.415	0.430	0.438	0.560	0.394	0.413	0.458
L1	0.411	0.252	0.317	0.442	0.249	0.549	0.469	0.377	0.380	0.406	0.337	0.335		0.228	0.335	0.340	0.399	0.517	0.278	0.400	0.423
L2	0.416	0.334	0.394	0.424	0.319	0.538	0.453	0.374	0.431	0.399	0.406	0.314	0.228		0.375	0.378	0.400	0.520	0.321	0.426	0.435
Martian specimen	0.464	0.347	0.355	0.427	0.264	0.454	0.390	0.396	0.432	0.409	0.385	0.415	0.335	0.375		0.364	0.394	0.519	0.393	0.407	0.396
S1	0.402	0.347	0.339	0.413	0.278	0.486	0.387	0.397	0.406	0.427	0.427	0.430	0.340	0.378	0.364		0.348	0.502	0.323	0.383	0.434
S2	0.476	0.377	0.415	0.404	0.350	0.523	0.429	0.334	0.313	0.323	0.463	0.438	0.399	0.400	0.394	0.348		0.576	0.483	0.417	0.403
S3	0.539	0.512	0.300	0.449	0.475	0.587	0.554	0.438	0.517	0.551	0.418	0.560	0.517	0.520	0.519	0.502	0.576		0.504	0.429	0.519
S4	0.404	0.272	0.332	0.505	0.246	0.569	0.502	0.368	0.403	0.488	0.437	0.394	0.278	0.321	0.393	0.323	0.483	0.504		0.450	0.500
STAL1	0.469	0.399	0.341	0.404	0.409	0.494	0.433	0.438	0.418	0.487	0.284	0.413	0.400	0.426	0.407	0.383	0.417	0.429	0.450		0.230
STAL2	0.556	0.454	0.367	0.421	0.442	0.501	0.482	0.445	0.453	0.490	0.252	0.458	0.423	0.435	0.396	0.434	0.403	0.519	0.500	0.230	

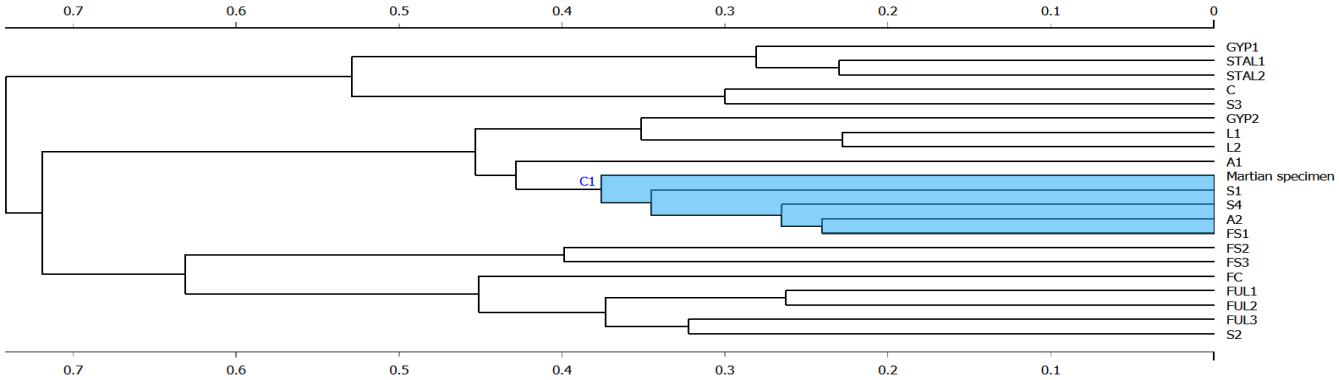

Fig 5 Hierarchical clustering (HC) dendrogram of the 21 images using Orange data mining image analytics software. Abbreviations for the various images are listed in Table 1. Specimens that group most closely to the Martian specimen are highlighted in blue.

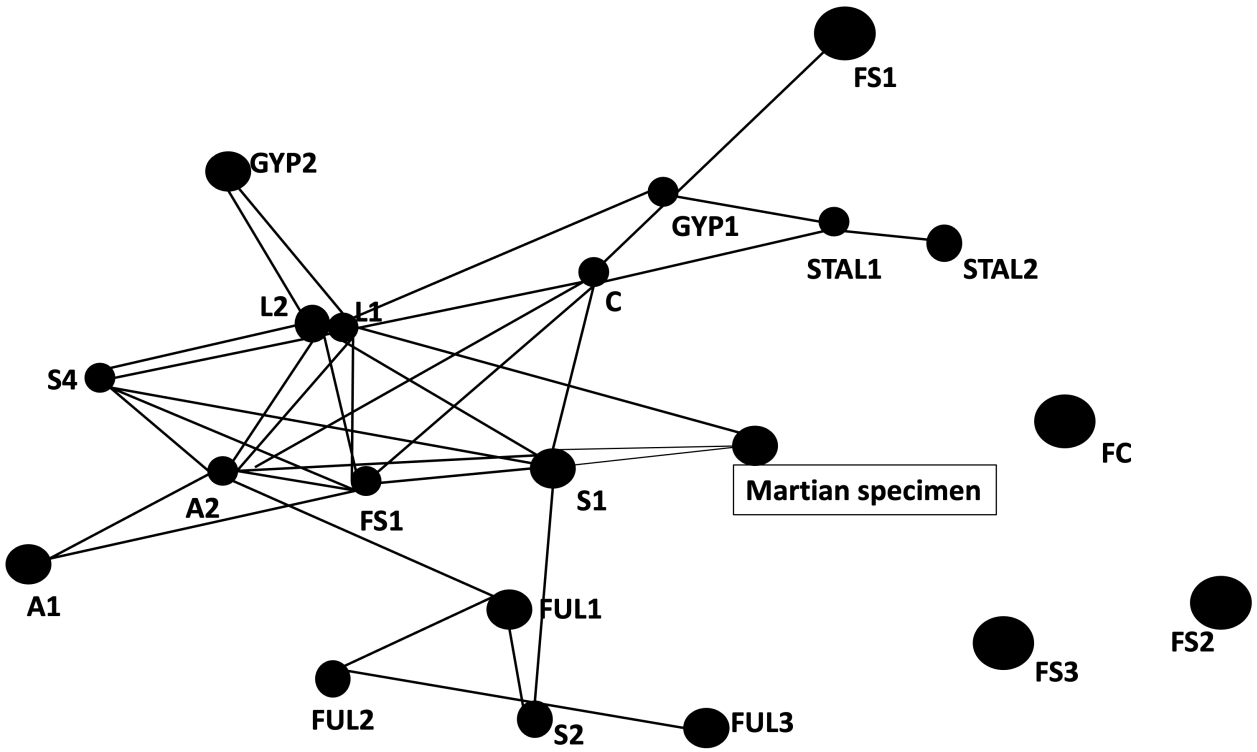

Fig 6. Multiple dimensional scaling (MDS) of the 21 images using deep learning and Orange data mining image analytics software. Abbreviations for the various images are listed in Table 1. Lines are pairings between similar images. Larger symbol sizes indicate less confidence in each image's position in the 2D approximation of the multi-dimensional model.

4. Discussion

The purpose of this study was to assess the utility of Orange data mining image analytics software for comparing Martian and terrestrial images. The analyses confirm the subjective impression reported in previous papers (Armstrong 2022; Joseph et al. 2022a) that the closest morphological affinity was to a living or fossil sponge (Phylum Porifera) with more remote similarities to the alga *Dasycladus*, the fruticose lichen *Evernia prunastri,* and a tenuous link to one of the specimens of fulgurite. Consistent with the presence of a sponge-like organism, in the past Gale crater may have periodically contained volumes of water including lakes, rivers and streams and today, has all the characteristics of a series of dried lakes (Grotzinger et al. 2014; Rampe, et al. 2020) which may be periodically replenished due to the waxing and waning of obliquity and resulting increases in temperature, atmospheric pressure, coupled with the melting of surface and subsurface glaciers (Joseph et al. 2022a).

Table 4. Results of the analyses for each of the four sets of images. Images are listed in order of affinity to the Martian specimen (abbreviations as in Table 1)

Processing	*Method of analysis*	
	HC	*MDS*
Original images	S1, S4, A2, FS1	S1, FS1, A2, L1
With 'edge detection'	FS2, A1, FS3	None detected
Binary ('outlined')	S2, FUL2	None detected
Binary ('skeletonised')	FS2, A1	FS2, A1

Specifically, there is a substantial evidence that Mars has been subjected to repeated episodes of changes in orbital obliquity over the last 4 billion years, including as recently as 400,000 to 110,000 years ago resulting in melting of glaciers, permafrost and subsurface ice thus replenishing oceans, lakes, and rivers as water floods over the surface and then stabilizes due to increased temperatures and atmospheric pressure (Joseph et al. 2022a). It has been proposed that life has evolved within these oceans of water only to become fossilized when obliquity declines. Moreover, rocks with deep and concave holes ('trace fossils') similar to those fashioned by mollusks have been photographed in the ancient lakes beds of Jazero Crater, Mars (Joseph et al. 2022b). These data support the hypothesis that, as on Earth, rocks along an ancient seashore at Jazero crater were colonised by rock-boring animals such as bivalves, and that these "trace fossils" are evidence of past life in the ancient inland seas of Mars.

The analysis is easy and rapid to perform, has provided a clear definition of the relative affinities of the Martian form to the various terrestrial specimens, and does not require either subjective interpretation or the laborious establishment and subsequent measurement of various metrics followed by PCA (Armstrong 2021a,b). Metrics can be difficult to both establish and measure accurately when employing Martian images. In addition, a particular limitation of PCA is that the analysis is strongly affected by the specific images selected and the metrics used to define them (Costello and Osborne 2005). The first limitation also applies to the present study. But further analyses could potentially include a very large number of images.

This study using Orange data mining image analytics to compare images raises several questions. First, should a Martian specimen be compared with a selected group of images or a large data base of images? If the former, as in the present study, then there is a degree of subjectivity in which images are selected for inclusion. Hence, inclusion of further living organisms could change the affinities established by the current analysis. Similarly, the discovery of abiogenic analogues that more closely resemble the Martian specimens could change the overall conclusion of the analysis. Nevertheless, a search of many hundreds of such images failed to reveal a credible abiogenic analogue of the Martian specimen. In fact, despite repeated efforts, biological but no abiogenic analogs for numerous other specimens has been reported.

If a large data base of images is included in the analysis, then many images may have little similarity to the specimen under investigation and this could also distort the conclusions. Second, should images be manipulated before being included in the analysis? Such manipulations might include adjustment of color, brightness and contrast, and the enhancement and 'sharpening' of images including 'edge detection', 'outlining', and 'skeletonisation' using an image analysis program, such as Image-J, or the removal of 'artifacts' such as arrows or other labels. The effects of these variables will need to be studied but preliminary investigations suggest that the results and interpretation are little affected by such artifacts as labels or arrows.

Nevertheless, the various types of processing, although not altering the overall conclusion of the study, that the closest counterpart is a living or fossil sponge, does alter which of the specimens is selected as a match. Each of the processing methods subtracts information from the image while at the same time emphasizing certain aspects such as the overall shape or branching pattern. In addition, the use of 'edge detection' may be counterproductive as it emphasises one feature of the specimens while the analysis of the original images considers all aspects of the complete image. It is likely that analysis of the original images may prove to be the most informative unless there are aspects of the specimens which require to be specifically emphasised. Third, how similar does a Martian specimen have to be to a terrestrial analogue to identify the latter as a credible match? This method of establishing the affinities of Martian specimens using this software relies on the assumption that if there is evidence of life on Mars, either living or fossilized, it will have morphological features which resemble those of terrestrial environments. Nevertheless, because of the long history of severe cold and dry conditions on Mars, any organisms that originally evolved are likely to have acquired further adaptive changes and therefore, would not necessarily closely resemble any terrestrial fossil or living organism. Hence, the method may be useful in identifying the general taxonomic affinity of a Martian specimen but a very close analogy to a terrestrial life form is unlikely.

The present example uses freely available and user friendly software and is the most straightforward application of the existing technology. Further developments could include enabling the algorithm to 'learn' the basic components which define a particular organism and then to be able to identify an unknown specimen from them. For example, extremophile lichens on Earth can be identified using several morphological criteria (Armstrong 2019, 2022). Recognition of possible 'lichen features' on Mars may enable the algorithm to calculate the probability that any Martian specimen with lichen-like present in extremophile lichens on Earth, may be needed to survive on Mars. Hence, one of the most extreme terrestrial habitats is represented by the cold, dry deserts of Antarctica, an environment which resembles Mars in some respects (Friedman 1977, 1982; Armstrong 2023).These habitats harbor life in the form of cyanobacteria and lichens which live within the surface layers of the rocks('endolithic' organisms). The Martian environment is even more hostile for lichens and further adaptations would presumably be required to survive. In these circumstances, it could also be argued that there may be little purpose in attempting to compare Martian specimens to terrestrial analogues. The problem is similar to

that encountered in interpreting the terrestrial fossil Pre-Cambrian 'Ediacaran' (McCall 2006) and the Cambrian 'Burgess Shale' faunas (Briggs et al. 1994) in which although some fossils can be referred to modern taxa, many others appear to have no obvious affinities. In the present circumstance, the challenge will be to predict how life on Mars may have diverged from that on Earth, given their different histories, and machine learning might be able to be used to predict those changes.

Our research was inspired by the paper of Godec and colleagues (Godec et al. 2019). This paper highlighted the potential of the Orange software for making image analysis accessible to a wider audience. What makes Orange particularly useful is that it's not only free but also works on regular computers and laptops. Even people without advanced computer skills can use it to create image analysis workflows, similar to that shown in Figure 3. Starting with a blank canvas, different tools or "widgets" can be dragged and dropped such as Import Images, Image Embedding, Distances, HC, and MDS, and are easy to connect, so that they perform complex calculations using Python, drawing from specialized deep learning libraries when needed. In fact, Orange provides links to useful YouTube videos suitable for viewers of all ages, demonstrating how these workflows can be created for various purposes.

In their 2019 paper, Godec and his team also emphasized the value of pre-trained deep convolutional networks. We used the Inception V3 network in our study, which was trained on millions of images from ImageNet, covering a wide range of subjects, both living and non-living. These deep networks work somewhat like the human visual system, adapting to recognize features in new and unfamiliar images. This technique is known as 'Transfer Learning', and it enables meaningful analysis even with small collections of images. It is particularly useful for studying isolated images from the surface of Mars, opening up exciting possibilities for exploring the likelihood of past or present life on the planet. It is even possible to envision children from all over the world using these tools to investigate the potential for life on Mars.

5. Conclusion

This study compared an unusual branched specimen photographed by the rover Curiosity MAHLI at Gale crater on sol 3396 with 20 possible terrestrial living, fossil, and abiogenic analogues, including examples of algae, lichens, sponges, corals, fulgurite, selenite, and stalagmites using Orange data mining image analytics software. The analysis obtained 2048 column vectors from each image and compared them to produce both a hierarchical classification and a 2D spatial display revealing the possible affinities of the specimen. The analysis confirmed previous interpretations that the overall shape and texture of the Martian specimen most closely resembles a terrestrial living or fossil sponge. Although, the analysis does not demonstrate definitively that the Martian specimen is a sponge, or a specific species of sponge, it suggests that further analysis of a larger variety of fossil and living sponges might provide a credible morphological analogue for this specimen. The study also demonstrated the value of the software in analyzing images from Mars and comparing them with possible terrestrial analogues.

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