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"This was to be a preliminary trip. Our object was to survey the ground for future operations rather than make them ourselves. A number of sites were to be examined and reported upon, with a view to deciding which would be the most profitable to excavate."
J.Wyndham, "The Last Lunarians"

Towards Lunar Archaeology

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Our Moon is a potential indicator of a possible alien presence near the Earth at some time during the past 4 billion years. To ascertain the presence of alien artifacts, a survey for ruin-like formations on the Moon has been carried out as a precursor to lunar archaeology. Computer algorithms for semi-automatic, archaeological photo-reconnaissance are discussed. About 80,000 Clementine lunar orbital images have been processed, and a number of quasi-rectangular patterns found. Morphological analysis of these patterns leads to possible reconstructions of their evolution in terms of erosion. Two scenarios are considered: 1) the collapse of subsurface quasi-rectangular systems of caverns, and 2) the erosion of hills with quasi-rectangular lattices of lineaments. We also note the presence of embankment-like, quadrangular, hollow hills with rectangular depressions nearby.. Tectonic (geologic) interpretations of these features are considered. The similarity of these patterns to terrestrial archaeological sites and proposed lunar base concepts suggest the need for further study and future *in situ* exploration.

1. Introduction

The idea of lunar archaeology was discussed long before space flight. In the 1930s, J.Wyndham (alias J.Beynon) wrote "The Last Lunarians" — a fictional report about an archaeological mission to the Moon[2]. In writing about the discovery of an ancient lunar artifact in the short story, *The Sentinel*, Arthur C. Clarke said: "There are times when a scientist must not be afraid to make a fool of himself"[3]. Today, the idea of exploring the Moon for non-human artifacts is not a popular one among selenologists. Yet, because we know so little about the Moon, the investigation of unusual surface features can only add to

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[1] Institute of Radio Astronomy, Nat. Acad. Sci. of Ukraine
[2] Wyndham, J. *Wanderers of Time*. London: Coronet Books, 1973, p. 117-134.
[3] Clarke, A.C. *The Sentinel*. N.Y.: Berkley Books, 1983, p. 143.

our knowledge. When we return to the Moon, it is possible that lunar archaeological studies may someday follow.

It has been argued[4,5] that the Moon could be used as an indicator of extraterrestrial visits to our solar system. Unfortunately, the detection of ET artifacts on the Moon is outside the interest of most selenologists due to their orientation towards natural formations and processes. It is also not of interest to mainstream archaeologists, as archaeology tends to adhere to a pre-Copernican geocentric point-of-view.

In 1992, the Search for Alien Artifacts on the Moon (SAAM) — the first privately-organized archaeological reconnaissance of the Moon — was initiated. The justifications of lunar SETI, the wording of specific principles of lunar archaeology, and the search for promising areas on the Moon were the first stage of the project (1992-95). Preliminary results of lunar exploration[6] show that the search for alien artifacts on the Moon is a promising SETI-strategy, especially in the context of lunar colonization plans. The aim of the second stage of SAAM (1996-2001) was the search for promising targets of lunar archaeological study. The goals of this second stage involved 1) developing new algorithms for space archaeological reconnaissance, 2) using these algorithms to detect possible archaeological sites on the Moon, and 3) examining the reaction of mainstream scientists to these results.

2. Methodology

It is generally accepted that the search for alien artifacts on the Moon is not necessary because there are none. Circular logic leads to a deadlock: no finds, hence no searches, hence no finds, etc. Given the success in using terrestrial remote sensing to find archaeological sites on Earth, can similar techniques be used to find possible artificial constructions on the Moon and other planets? Hardly, if planetologist think only in terms of natural formations. For example, the ancient Khorezmian fortress Koy-Krylgan-kala in Uzbekistan, constructed between the 4th century BC to the first century AD, appeared as an impact crater before excavation in 1956 (Fig. 1). On the Moon, Koy-Krylgan-kala would not be perceived among all of the impact craters.

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[4] Arkhipov, A.V. "Earth-Moon System as a Collector of Alien Artefacts", *J. Brit. Interplanet. Soc.*, 1998, **51**, 181-184.
[5] Arkhipov, A.V., and Graham, F.G. "Lunar SETI: A Justification", in *The Search for Extraterrestrial Intelligence (SETI) in the Optical Spectrum II*, ed. S.A. Kingsley & G.A. Lemarchand, SPIE Proceedings, Vol. 2704, SPIE, Washington, 150-154, 1996.
[6] Ibid.

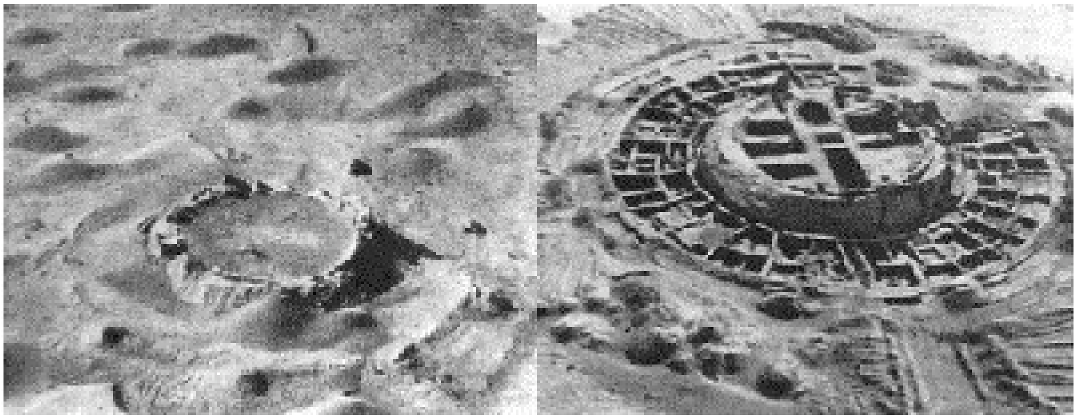

Fig. 1 The ancient Khorezmian fortress Koy-Krylgan-kala appeared as an impact crater on the air photo (left); its artificiality is obvious after the excavations in 1956 (right)[7].

Instead of the current presumption that all surface features are natural, an alternative search strategy is to be open to the possible existence of artifacts. If we are open to this possibility, then one can extend Carl Sagan's search criteria for detecting signs of life on Earth[8] to other planets:

> "Let us first imagine a photographic reconnaissance by orbiter spacecraft of the Earth in reflected visible light. We imagine we are geologically competent but have no prior knowledge of the habitability of the Earth. Photography of the Earth at a range of surface resolutions down to 1 km reveals a great deal that is of geological and meteorological interest, but nothing whatever of biological interest. At 1 km resolution, even with very high contrast, there is no sign of life, intelligent or otherwise, in Washington, London, Paris, Moscow, or Peking. We have examined many thousands of photographs of the Earth at this resolution with negative results. However when the resolution is improved to about 100 m, a few hundred photographs of say 10 km x 10 km coverage are adequate to uncover terrestrial civilization. The patterns revealed at 100 m resolution are the agricultural and urban reworking of the Earth's surface in *rectangular arrays*... These patterns would be extremely difficult to understand on geological grounds even on a highly faulted planet. Such rectangular arrays are clearly not a thermodynamic or mechanical equilibrium configuration of a planetary surface. And it is precisely the departure from thermodynamic equilibrium which draws our attention to such photographs."

In 1962 Sagan spoke on the possibility of discovering alien artifacts on the Moon stating that "Forthcoming photographic reconnaissance of the moon from space vehicles — particularly

[7] Amalrik A.S. & Mongait A.L. *In Search for Vanished Civilizations*. Moscow: Acad. Sci. of USSR, 1959, p. 128-129 (in Russian).
[8] Sagan, C. The recognition of extraterrestrial intelligence, *Proc. R. Soc. Lond*. B. 1975, **189**, p. 143-153.

of the back — might bear these possibilities in mind[9]." Rectangular patterns on air-space photos are recognized as signs of human culture in the remote sensing of the Earth and air archaeology[10]. It seems reasonable then to search for rectangular patterns on the Moon. For example, assume that the equivalent of proposed modern lunar bases were built long ago (e.g., 1-4 billion years ago) on the Moon. Such structures would have been built under the surface for protection from ionizing radiation and meteorites. Today these ancient structures might appear as eroded systems of low ridges and depressions, covered by regolith and craters (Fig. 2).

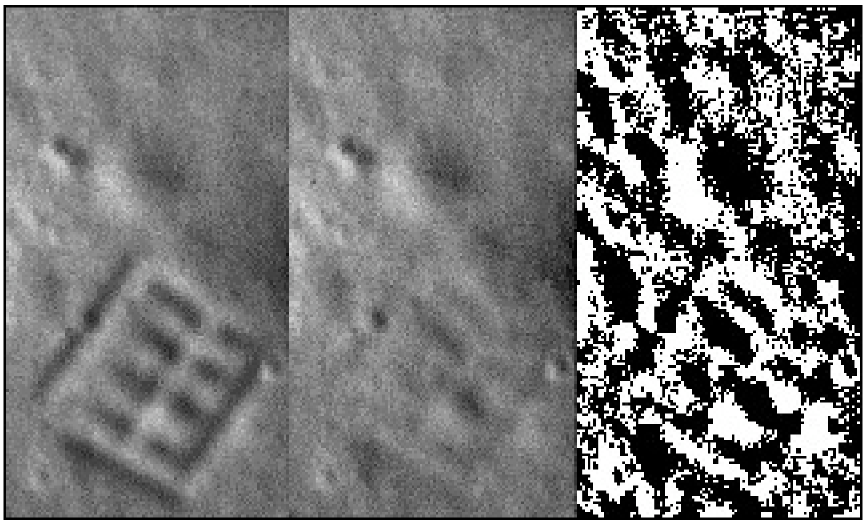

Fig. 2 Simulation of probable HIRES view of ancient settlement on the Moon (left). The erosion wipes off the surface tracks of construction (center), but the SAAM processing could reveal the rectangular anomaly (right).

A wealth of lunar imagery collected by the Clementine probe are available in digital form[11]. Initial SETI studies[12] used images from the ultraviolet-visible (UVVIS) camera. The resolution of UVVIS images is ~200 m. According to Sagan's detection criteria, this resolution would not be sufficient even to detect the presence of our own civilization on Earth. Studies of the Moon at this resolution would probably not reveal any convincing evidence of the existence of artificial structures. On the other hand, Clementine's high-resolution (HIRES) camera produced images of adequate resolution (9-27 m), but they are much more numerous (~ 600,000 images total) and they are thus largely unstudied. The next section discusses algorithms for automatically scanning large numbers of HIRES images for potential artifacts.

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[9] Carl Sagan in 1962 on Lunar SETI, *Selenology*, 1995, **14**, No. 1, p.13.
[10] Holz, R.K. "Cultural features imaged and observed from Skylab 4", In: *Skylab Explores the Earth*. NASA SP-380. Washington: NASA, 1977, p.225-242.
[11] DoD/NASA, Mission to the Moon, *Deep Space Program Science Experiment, Clementine EDR Image Archive*. Vol. 1-88. Planetary Data System & Naval Research Laboratory, Pasadena, 1995 (CDs).
[12] Carlotto, M., Lunar Mysteries, *Quest for Knowledge*, 1997, **1**, No. 3, p. 61.

3. Algorithms

3.1 Preliminary Fractal Test

As a rule, the structure of natural landscapes is self-similar over a range of spatial scale. For example, lunar craters between 10^{-1} m to 10^{4} m in size appear similar in structure. In contrast to the self-similar structure of natural features, the structure of artificial objects is expressed over a narrower range of scale. Hence, possible artifacts in an image might be recognized as anomalies in the distribution of spatial detail as a function of scale. The search for such anomalies is the essence of the fractal method proposed by M.C. Stein and M.J. Carlotto[13,14]. Unfortunately their method is too computationally-intensive to process all of the candidate HIRES images (~80,000).

An alternative algorithm that is simpler and faster was used for the same purpose. Let M(r) be the probability distribution of the distances between local minima in brightness along horizontal lines in an image. M(r) thus provides a measure of the size distribution of image detail. At long scales, this function can be approximated by the fractal power law:

$$M(r) \sim r^{\nu} \tag{1}$$

As artificial objects have some typical size, their presence should increase the squared residuals of linear regression:

$$\log M(r) = \nu \log r + C \tag{2}$$

where C is a constant. According to empirical results, M(r) of the HIRES images can be approximated by a power law at $r \geq 5$ pixels. The regression is calculated from $5 \leq r \leq 30$ pixels (i.e., over a scale range from 50 to 900m).

Images are divided into K=12, 96x96 pixel regions. In each region the best model parameters are calculated by least squares, and the average of the squared residuals determined:

$$\sigma_k^2 = \frac{g_k}{N} \sum_{i=1}^{N} [\log M(r_i) - \nu \log r_i - C]^2 \tag{3}$$

where k is the number of the test square, g_k compensates for gain variations across the sensor, and N is the number of scales. The average dispersion is estimated from these regional squared residuals.

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[13] Carlotto, M.J. and Stein, M.C., A Method for Searching for Artificial Objects on Planetary Surfaces, *J. Brit. Interplanet. Soc*., 1990, **43**, p. 209-216.

[14] Stein, M.C., "Fractal image models and object detection," *Proc. Society of Photo-optical Instrumentation Engineers,* Vol 845, pp 293-300, 1987.

An analysis of 733 HIRES images using the 0.75 micrometer filter, from orbits 112-115 (up to 75 deg. latitude) shows the distribution of residuals to be Gaussian in form. According to the Student's criterion for K=12 estimates, if the inequality

$$\left(\sigma_k - \langle\sigma\rangle\right) > 1.796 \sqrt{\frac{1}{K-1} \sum_{k=1}^{K} \left(\sigma_k - \langle\sigma\rangle\right)^2} \tag{4}$$

is true in any test square, this area could be considered as statistically anomalous with a probability of 0.95.

3.2 Detailed Fractal Test

A modified version of Stein's fractal method was used as a more detailed test. First, the range of HIRES image brightness was increased linearly up to 256 gradations. Then the image could be considered as an intensity surface in a 3-D rectangular frame of coordinates (x and y are the pixel coordinates, and z the brightness). Stein's method can be thought of as enclosing the image intensity surface in volume elements. These volume elements are cubes with a side of 2r, where r is the scale in terms of pixel coordinates or brightness. Let V(r) be the average minimal volume of such elements enclosing an image intensity surface at some point. Then the surface area is A(r) = V(r)/2r. As a function of scale, A(r) characterizes the size distribution of image details. The fractal linear relation between log A(r) and log r is a good approximation for natural landscapes. However, fractals do not approximate artificial objects as a rule. This is why Stein used the average of the squared residuals of the linear regression

$$\log A_r = \beta \log r + \gamma \tag{5}$$

As a measure of artificiality. Unfortunately, the value of the squared residuals depends on the number of pixels in an image. Therefore, it is difficult to compare images with different sizes. Moreover, shadows increase the residuals and generate false alarms. These problems can be resolved by the non-linear regression:

$$\log A_r = \alpha (\log r)^2 + \beta \log r + \gamma \tag{6}$$

where the 'artificiality parameter (alpha) is independent of the image size.

Fig. 3 plots alpha of a random set of images representing the natural lunar background (crosses), and the set of images containing anomalous objects (squares). The shadows lead to values of alpha greater than zero, but anomalous objects have values less than zero. At any Solar zenith angle, Z_{sun}, the anomalous formations have systematically lower alpha than the random set of HIRES images. The average linear regression relating alpha of the random set and Z_{sun} is shown as a dashed line where the standard deviation of the crosses from this regression is 0.0113. A deviation of 3 sigma (solid line) is adopted as a formal criterion for the final selection of candidate objects.

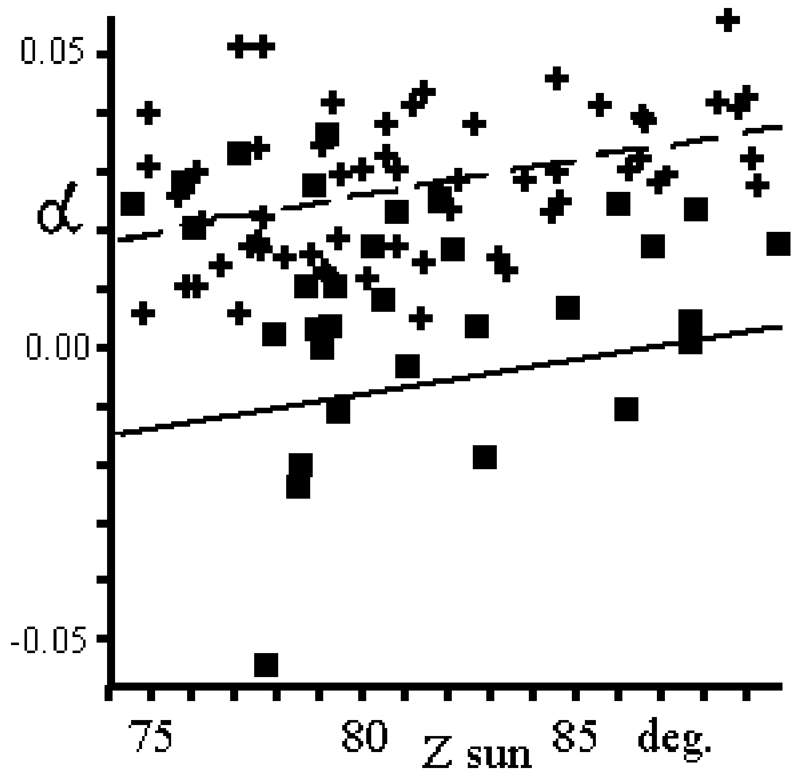

Fig. 3 Selection of lunar features based on 'artificiality parameter' alpha

3.3 Rectangle Test

The rectangle test reveals rectangular patterns of lineaments on the lunar surface. For each pixel of the image, a second pixel at a distance of 6 pixels and a given position angle is selected. Let N be the total number of pixel pairs, and n be the number of pairs where the pixel brightnesses are equal. The function

$$W(\varphi) = n/N \tag{7}$$

characterizes the anisotropy of the image in terms of position angle. To correct for camera effects it is normalized by its average over many images. The anisotropy is smoothed and position angle maxima are found. The maxima are the orientations of lineament groups. If there are 90 deg. ± 10 deg. differences between maxima, the image is classified as interesting.

3.4 SAAM Transformation

To aid in false alarm rejection, the SAAM transformation (Fig. 2) of the image was used to enhance subtle details of the lunar surface. This transformation involves smoothing the image over a sliding circular window of radius R, and subtracting the result from the initial image. Pixel that are brighter than the smoothed level (difference greater than zero) are labeled as 'white'; the others are 'black'. Clipping helps us to see details of both low and high contrast. Moreover, large details (greater than R in size) are de-emphasized and so do not interfere with smaller-sized features.

3.5 SCHEME Algorithm

The SCHEME algorithm searches for local extremities of lunar relief. It does so by detecting peaks in the image intensity surface in the direction of the sun. An example of the SCHEME algorithm is shown in Fig. 4.

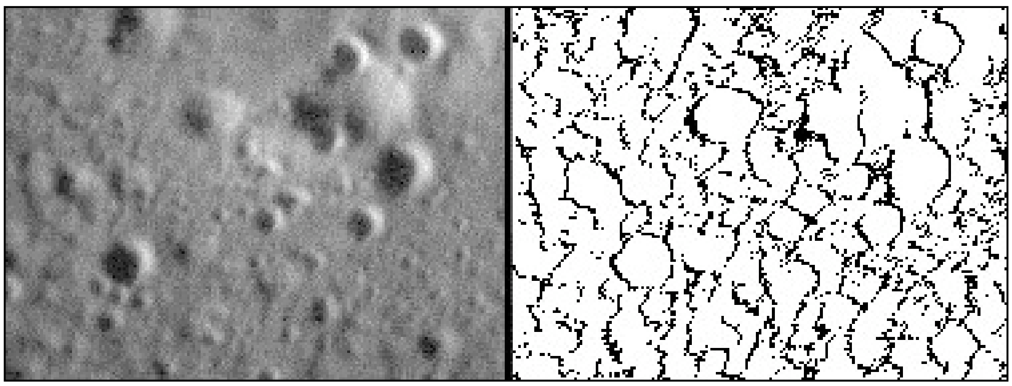

Fig. 4 The image LHD0331A.062 and a map of relief extremities found by the SCHEME algorithm.

3.6 Geological Test

J. Fiebag has suggested that when parallelism exists between a structure and the lineaments of its surroundings, it is likely to be natural[15]. Although human activities do sometimes correlate with geological lineaments (e.g. rivers), the conservative Fiebag test was applied to the lunar finds.

The lineament orientation of surroundings was estimated by the rectangle test technique applied to the ultraviolet-visible (UVVIS) camera. The UVVIS image covers 196 times the HIRES area with the same 0.75 micrometer filter. Only peaks in the anisotropy (Eq. 7) with statistical significance of greater than 0.9 were taken into account. If one of the two directions of the rectangular formation on a HIRES-image is within 10 deg. of any significant UVVIS direction, the object is not considered as interesting. This test rejects about 60% of finds.

[15] Fiebag J. Analyse tektonischer Richtungsmuster auf dem Mars. Kein Hinweise auf künstliche Strukturen in der südlichen Cydonia-Region, *Astronautik*, 1990, Heft 1, 9-13, S. 47-48.

4. Finds

4.1. Catalogue

Only the polar HIRES images of ±75 deg. to ±90 deg. latitudes were processed in our survey because of their oblique lighting. The preliminary fractal, rectangular, geological tests and the SAAM filter were used with two additional tests:

- Shadow Filter — In order to reduce false alarms excessively shadowed images were discarded. If more than 5% of pixels are dimmer than 10% of the maximum brightness amplitude, that image was ignored. Files of less than 13 KB size were discarded as well.

- FREX — For filtering of shadow interference after the preliminary fractal test, the following procedure was used: The artificiality parameter alpha was computed as in Section 3.2 section, but for only 1 of every 5 points to speed up the analysis of the images. The average linear regression relating alpha of the random image set and zenith angle of the Sun was calculated by this simple algorithm. If the value of alpha for an image was lower than the regression value minus 1/2 of its standard deviation, the image was selected.

The preliminary fractal test, shadow filter, FREX and rectangular tests selected ~5% of the images as interesting. The selected files were SAAM filtered and tested visually. About 97% of the selections were ignored after SAAM testing. The remaining 128 finds are catalogued. Only 47 catalogued images were retained after the geological test. Their orientations were different by 10 deg. or more from significant directions of background lineaments. Finally, only 18 of these 47 images were selected as most interesting by the full fractal test. Their alpha values deviate from the regression line for 100 random images by more than 3 standard deviations.

The images of highest interest are shown in Table 1. (The full set of images are listed in Appendix A with the images of highest interest shown in bold.) The finds in the catalogue are described as systems of simple *quasi-rectangular* elements: depressions (d), furrows (f), quadrangle hills (h), rectangular patterns of craterlets (p), and ridges (r). Thus, an abbreviation such as 'dr' in the last column is a system with quasi-rectangular depression(s) and quasi-rectangular ridges. This method of description is convenient for morphological analysis.

Table 1 Catalogue of highest interest finds

Longitude[16] deg.	Latitude deg.	File[17]	Elements
20.03	-81.24	LHD0395A.160	p
28.35	79.10	LHD5502Q.290	f
31.21	78.82	LHD5256Q.293	d
53.95	-83.54	LHD0287A.146	rd
179.43	89.72	LHD5696R.248	fp
191.54	83.21	LHD5416R.230	r
192.83	-81.40	LHD0096A.230	dr
192.90	-76.89	LHD0392B.097	f
232.01	-76.20	LHD0210B.215	f
246.08	81.88	LHD7638R.343	fh
250.58	-85.48	LHD0193A.073	r
261.17	86.87	LHD5466R.208	dr
266.18	-83.86	LHD0278A.068	r
269.63	85.11	LHD5650R.072	d
272.70	82.72	LHD5562R.202	r
300.02	79.68	LHD5345Q.059	hd
301.28	85.55	LHD6749R.318	r
306.10	-77.54	LHD0387B.055	dr

Concerning the lower-ranked images, it is noted that human activity sometimes correlates with geological lineaments (e.g. valleys, rivers, deposits around faults, and others) as mentioned earlier. That is why a negative result of the geological test does not necessarily indicate a natural object. A positive result would, however, provide further evidence of artificiality. Similarly, eroded objects could be of low contrast in orbital imagery. Their fractal properties might not be significantly different from background, and so a negative fractal test result could undervalue the find. For these reasons, all of the finds in Table 1 are of potential interest for lunar archaeological reconnaissance.

4.2. Morphology

There are two main types of finds:

Quasi-rectangular patterns of depressions ('wafers') — About 69% of the finds are of this type. A wafer is a cluster of rectangular depressions with rectangular ridges between them. Such a pattern may be seen in the example in Fig. 5. Presumably, an isolated, single rectangular depression could be considered an extreme form of this type. Moreover, there are transitional forms from rectangular patterns of craterlets to wafers. In Table 1 wafers have

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[16] Coordinates of the image center.

[17] DoD/NASA, Mission to the Moon, *Deep Space Program Science Experiment, Clementine EDR Image Archive*. Vol. 1-88. Planetary Data System & Naval Research Laboratory, Pasadena, 1995 (CDs).

descriptions with d, dr, or p elements. The typical size of a wafer is 1-3 km. The size of a depression in a wafer is 0.1-2 km. Quasi-rectangular patterns of depressions occur in smooth terrains, e.g., between craters, or at the bottom of large-scale craters.

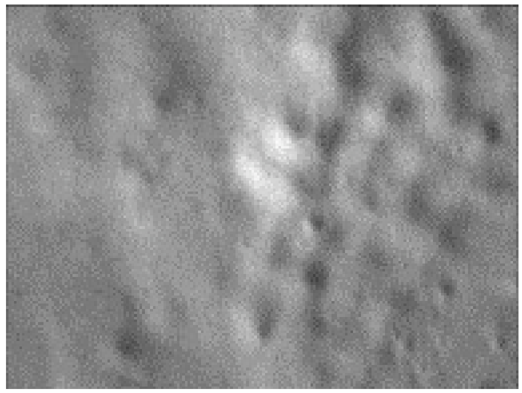

Fig. 5 The example of a *wafer* find (image LHD5472Q.287).

Quasi-rectangular lattices of lineaments ('lattices') — These comprise about 30% of the finds. A lattice is a complex of interlacing, broken ridges or furrows, which form a quasi-rectangular pattern (Fig. 6). This morphological type is present in Table 1 as complexes of r and/or f elements without d. These lineaments have a typical width of ~50 m and cover ~1 sq. km. in territory. Lattices occur on slopes and hill tops, where the regolith layer is thinnest. Apparently, what we see is subsurface structure rather than some organization of regolith.

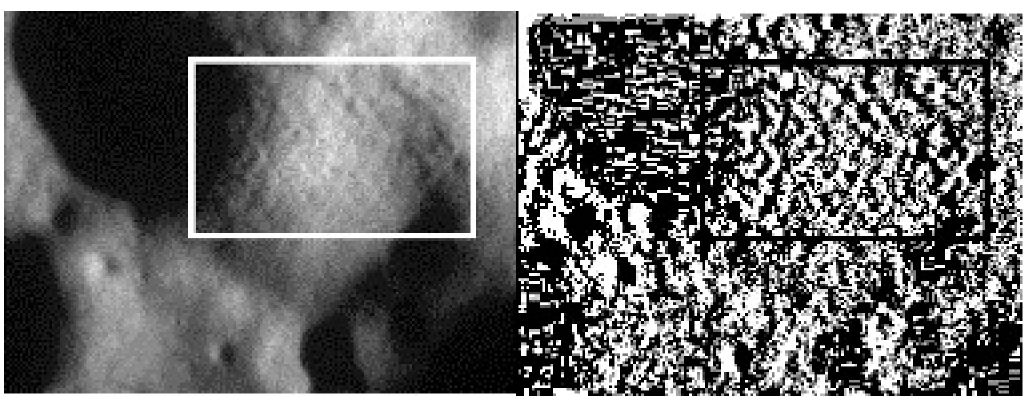

Fig. 6 The SAAM processing reveals the lattice pattern on the HIRES image LHD5165R.171.

Besides wafers and lattices, quadrangle hills are worthy of separate description (Fig. 7). The hills are located in formations of both morphological types. The dimensions of such hills are 0.3-1 km. Usually the quadrangle hill has a craterlet on its top. Sometimes the top depression is so large that the hill appears hollow. Rectangular depressions around hills are a rarity on the Moon, but are common for man-made mounds on Earth.

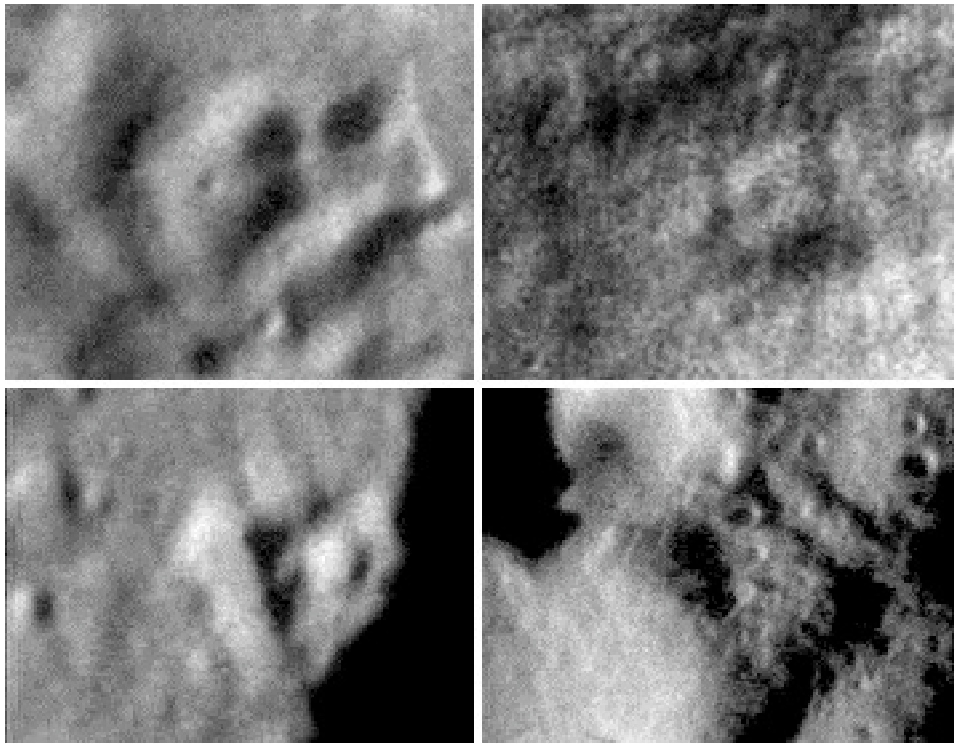

Fig. 7 Hollow quadrangle hills with rectangular depressions around them could be lunar embankments.

4.3. Interpretations

The possible evolution of these structures over time can be visualized from the available images. The reconstruction of wafer evolution is shown in Fig. 8. The simplest, probably the first stage formation, is a regular pattern of craterlets (Fig. 8a). Hypothetically, this could be the result of the collapse or drainage of regolith into subsurface caverns. Expanding craterlets become angular. Then a rectangular lattice of ridges appears between them (Fig. 8a,b). The rectangular lineaments around the formation (Fig. 8c) show a regular and local structure suggestive of subsurface caverns. A possible cavern system is seen after its total collapse (Fig. 8d). The bottom collapses (Fig. 8e) and slope terraces[18] in rectangular depressions suggest several levels of caves.

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[18] Arkhipov A.V. "Earth-Moon System as a Collector of Alien Artefacts", *J. Brit. Interplanet. Soc.*, 1998, **51**, 181-184.

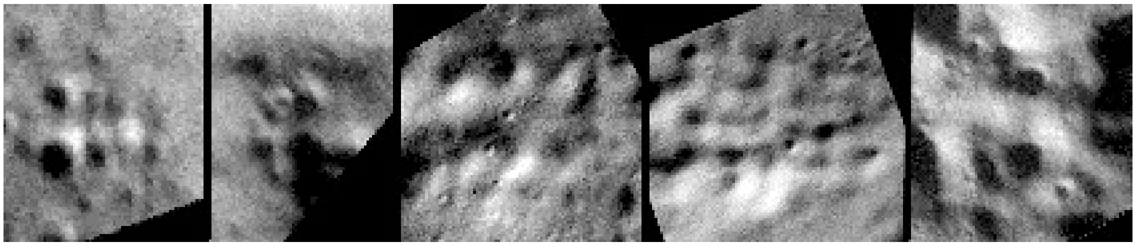

Fig. 8 Wafer examples in evolutionary order, from left to right: (a) LHD0316A.083, (b) LHD0470B.112, (c) LHD5443Q.291, (d) LHD5472Q.287, and (e) LHD5661R.068.

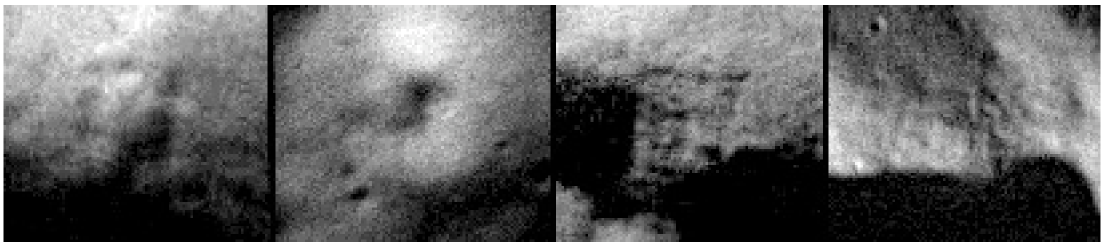

Fig. 9 Lattice examples in evolutionary order, from left to right: (a) LHD0558B.072, (b) LHD5559Q.279, (c) LHD6749R.318, and (d) LHD6158R.320.

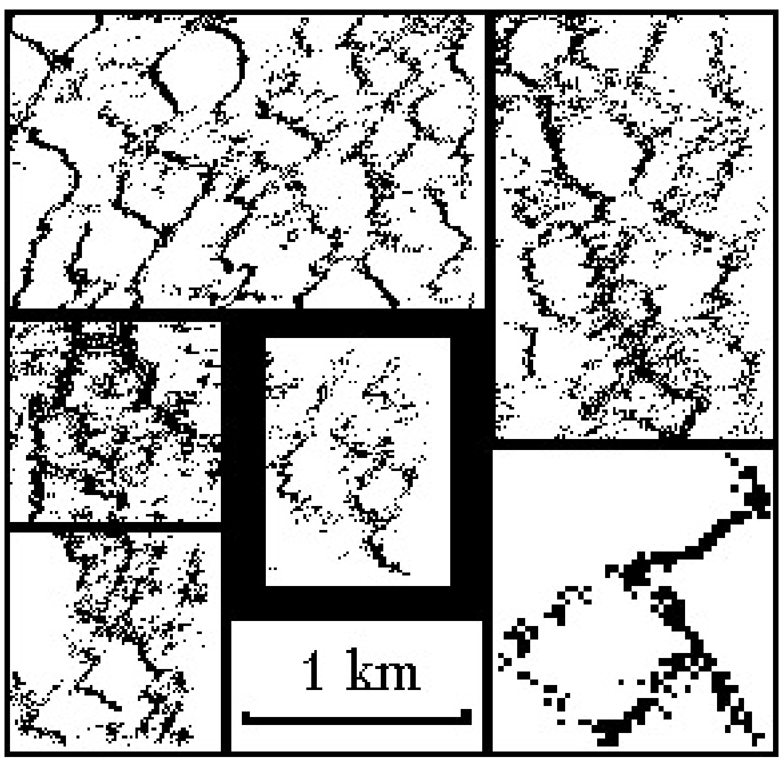

Fig. 10 Hidden rectangular patterns on the schemes (local extremities of relief) of HIRES images LHD0146A.210, LHD0331A.062, LHD0558B.072, LHD4691Q.253, LHD5243Q.208, and LHD6158R.320.

The lattice evolution could be interpreted in terms of erosion as well (Fig. 9). Apparently, the first (simplest) stage of a lattice is the quasi-rectangular system of narrow furrows/cracks (Fig. 9a). The cracks expand (Fig. 9b) and transform into a quasi-rectangular pattern of ridges (Fig. 9c). Fig. 9d shows a quadrangle mesa-like hill surrounded by a ridge system (enhanced using a high-pass filter). Apparently, such ridges are a relatively stable aspect of the hill they reside on.

Intact subsurface caverns or very eroded wafers and lattices are almost invisible in low contrast images. Indeed, some rectangular patterns are found in the relief-enhanced schemes (Fig. 10). A few elements are discernable in the original images. For example, the lattice seen in the bottom-right corner of the scheme in Fig. 4 is just barely perceivable in the original image.

Fig. 11 The air view of the Ancient Assyrian ruins of Assur resemble the lunar *lattice* in Fig. 6.

These rectangular systems of depressions and ridges resemble terrestrial ruins. For example, the patterns in Figures 6 and 10 are similar to the Ancient Assyrian ruins of Assur[19] (Fig.11).

For comparison, the detailed fractal test (Section 3.2) is used to compute the artificiality parameter (α in Eq. 6) over the random set of HIRES images (MOON), our finds (FINDS)

[19] Hrouda B. *Der Alter Orient*. Hamburg: C.Bertelsmann, 1991, S.115.

and a collection of air-space photos of terrestrial archaeological objects[20,21] (ARCHAEOLOGY). Fig. 12 shows the resultant histograms. It is possible that alpha values of the lunar finds are shifted towards the geological background because of the thick regolith cover. Still, some finds have the same alpha values as terrestrial archaeological sites.

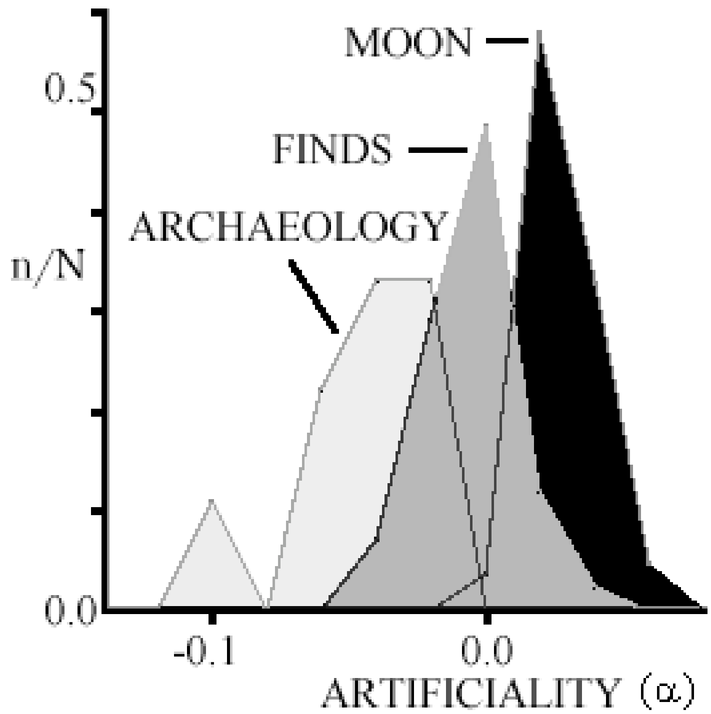

Fig. 12 The artificiality parameter for the lunar background (MOON), the finds, and terrestrial archaeology.

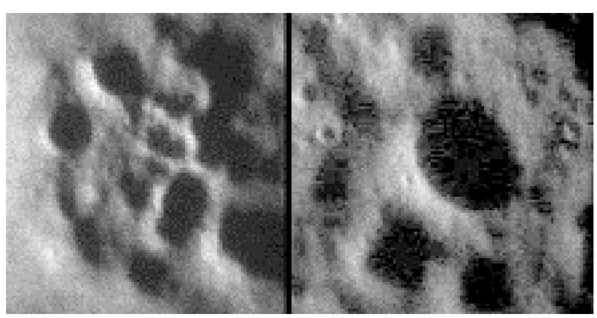

Fig.13 Argument against the geological fractures: the compact groups of neighbouring rectangular and round depressions of same size (LHD5705R.282 and LHD5814R.295).

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[20] Fowler M.J.F. Examples of Satellite Images in Archaeological Application (http://ourworld.compuserve.com/homepages/mjff/examples.htm)

[21] Roney J. Cerro de Trinchera Archeological Sites, *The Aerial Archaeology Newsletter.* Vol. 1, No. 1, 1998 (http://www.nmia.com/~jaybird/AANewsletter/RoneyOnTrincheras.html and She_in_shadow.html)

Many lunar geologists explain rectangular depressions on the Moon in terms of fractures (structural features) at the surface that were present before the impact events which formed the craters. We have found compact groups containing rectangular and round depressions of the same size (Fig. 13). Wafers and lattices appear too localized and regular in form to be tectonic features or jointing patterns resulting from multiple impacts. These are reasons to doubt a geological interpretation for all rectangular formations.

In proposed lunar base concepts, the rectangular patterns of subsurface constructions would be visible on the surface[22,23,24]. Such complexes could thus appear as wafer or lattice patterns. Subsurface, rectangular, multilevel caves are unknown in lunar geology. However, they are usually considered in modern plans for lunar bases, as are hollow hills (Fig. 14). Quadrangular and hollow hills on the Moon are thus worthy of attention as well.

Fig. 14 Modern concept of a lunar base within a hollow hill. Compare with Fig. 7.

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[22] Stroup T.L. Lunar Bases of the 20th Century: What Might Have Been, *J. Brit. Interplanet. Soc.*, 1995, **48**, p. 3-10.

[23] Matsumoto S., Yoshida T., Takagi K., Sirko R.J., Renton M.B., McKee J.W. Lunar Base System Design, *J. Brit. Interplanet. Soc.*, 1995, **48**, p. 11-14.

[24] Sadeh W.Z. & Criswell M.E. Inflatable Structures for a Lunar Base, *J. Brit. Interplanet. Soc.*, 1995, **48**, p. 33-38.

Of course, some or all of our finds could be geological formations. But the possibility that they could be archaeological features is so important that it should not be ignored *a priori*. Ultimately, only human exploration of the Moon will determine whether these features are artificial or natural in origin.

5. Scientific Reaction

The reaction of mainstream science to this study is perhaps the most interesting result of our project. There is a paradoxical contradiction between the vision expressed in science fiction and the agendas of scientific research. Unfortunately, idea of artificial objects on the Moon has been discredited by sensational press[25]. As a result, serious lunar research is not of interest to editors of scientific journals or even popular science magazines.

As an experiment, popular reports of our work were submitted to *Archeologia* (France), *Sky and Telescope* (USA), and *Spaceflight* (UK). None of them responded. *Scientific American* (USA) sent inspiring words: "I found your discussion in the latest META news interesting. Please let me know how the research progresses in the future... The search for such artifacts is certainly an important one... As your and other searches progress, we may want to have an article about the effort." Not even the hint of interest in extraterrestrial archaeology has yet appeared in *Scientific American*.

Correspondence with scientific journals is rather predictable. For example, the reviewer of the *Journal of the British Interplanetary Society* wrote: "The problem with Arkhipov's work is that he has not tried to explain his features in any way other than in terms of alien artifacts... Perhaps the author could be persuaded to develop his technique and write a paper on that rather than its use in finding ruins on the Moon?" Archaeologists, as a rule, don't theorize on natural explanations. They explore *in situ*. To find, we must search. Unfortunately, planetary geologists have no interest in conducting archaeological searches. That is why even discussion on archaeological reconnaissance of the Moon is taboo for the referees.

Strangely, *UFO Magazine* (UK), *UFO Magazine And Phenomena Report* (USA), and *Flying Saucer Review* (UK) are also silent about our work.

The reaction of the SETI community is especially interesting. According to the director of the SETI Institute, Dr. Seth Shostak, "I think the main problem with taking serious action in these regards is the lack of funding and the setting of priorities. This is, alas, always a problem for SETI as there are still only a rather small number of researchers involved, and they are presently more disposed to search for signals than for artifacts." Even followers of E. von Daniken (*Ancient Astronauts Society* and *Archaeology, Astronautics & SETI Research*

[25] Childress D.H. *Extraterrestrial Archaeology*. Kempton: Adventures Unlimited Press, 1999, p. 1-168.

Association) ignore lunar archaeology. Although the *SETI League*, *Society for Planetary SETI Research (SPSR),* and the Russian *SETI Center* support these studies, few scientists dare to search for evidence of extraterrestrial intelligence on the Moon.

Serious interest in archaeological reconnaissance of the Moon is practically nonexistent in the planetary science community. Yet, as revealed by the SAAM project, patterns similar to terrestrial archaeological sites do exist on the Moon. Hopefully, lunar scientists may someday be more willing to consider the exciting possibility of non-human artifacts on the Moon.

6. Conclusions

It is shown that computerized archaeological reconnaissance of the Moon is practical. The proposed methods can be used for more extensive lunar survey, and for planetary SETI in general.

About 80,000 Clementine lunar orbital images have been processed, and a number of quasi-rectangular patterns were found in accordance with Sagan's criterion for the detection of intelligent activity in satellite imagery. The morphological analysis of these finds leads to the reconstruction of their evolution in terms of erosion. Two possible evolutionary sequences can be constructed: 1) the collapse of subsurface quasi-rectangular systems of caverns, and 2) the erosion of hills with quasi-rectangular lattices of lineaments. In addition, embankment-like, quadrangle and hollow hills with rectangular depressions were also observed.

These finds resemble terrestrial archaeological sites and modern lunar base concepts. It is recommended that they be explored *in situ* as possible artifacts.

A catalogue of promising objects for archaeological reconnaissance of the Moon has been compiled. Whether they prove to be artificial or not, these features are examples of unusual lunar geology and merit further study.

Modern science and society are not yet prepared for the archaeological reconnaissance of the Moon. Nevertheless, a discussion on lunar archaeology will likely occur following the eventual colonization of our satellite.

Geological interpretations of lunar relief are well known, but we must take into consideration other possibilities as well.

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Appendix - Complete Catalogue of Finds

Longitude[26] deg.	Latitude deg.	File[27]	Elements
11.05	89.16	LHD5814R.295	d
13.63	85.57	LHD5741R.295	d
16.08	-76.10	LHD0480B.030	f
20.03	**-81.24**	**LHD0395A.160**	**p**
20.69	-79.70	LHD0159B.293	dr
22.50	80.63	LHD5686R.160	r
25.38	75.50	LHB5443Q.291	prf
28.25	-76.50	LHD0132B.290	dr
28.35	**79.10**	**LHD5502Q.290**	**f**
31.16	80.78	LHD5833R.157	f
31.21	**78.82**	**LHD5256Q.293**	**d**
32.97	79.60	LHD5538Q.289	f
33.55	77.27	LHD5715Q.156	dr
33.57	77.05	LHD5713Q.156	dr
35.45	81.20	LHD5555R.289	rfd
37.00	77.58	LHD5472Q.287	pr
37.18	79.86	LHD5525Q.287	df
41.93	-82.88	LHD0280A.151	fd
43.09	86.94	LHD5724R.286	dr
44.05	-75.87	LHD0445B.151	r
51.34	-83.68	LHD0233A.147	f
53.95	**-83.54**	**LHD0287A.146**	**rd**
56.88	87.01	LHD5705R.282	dr
60.29	79.20	LHD5559Q.279	d
60.30	85.14	LHD5636R.280	p
108.97	-76.82	LHD0412B.127	rhf
109.85	-82.38	LHD0344A.126	d
113.40	82.50	LHD5350R.260	fdr
123.50	86.07	LHD5652R.126	df
124.55	-82.47	LHD0282A.121	d
128.05	80.00	LHD5375R.254	?
128.25	-78.26	LHD0162B.253	f
128.41	-76.13	LHD0191B.253	r
128.83	82.91	LHD5459R.254	dr
130.26	-82.91	LHD0073A.252	d
130.33	-82.75	LHD0274A.119	rp
130.52	79.32	LHD4691Q.253	pf
130.71	80.68	LHD4722R.253	dr

[26] Coordinates of the image center.
[27] DoD/NASA, Mission to the Moon, *Deep Space Program Science Experiment, Clementine EDR Image Archive*. Vol. 1-88. Planetary Data System & Naval Research Laboratory, Pasadena, 1995 (CDs).

131.20	-78.77	LHD0111B.252	dr
135.66	80.05	LHD4807R.251	?
137.97	-84.74	LHD0276A.116	dr
139.41	-86.30	LHD0184A.115	f
145.91	77.84	LHD5288Q.247	f
148.00	-81.36	LHD0248A.113	f
148.41	-79.04	LHD0305B.113	d
149.69	-84.26	LHD0231A.112	f
150.71	-81.43	LHD0315A.112	rd
151.29	-77.99	LHD0415B.112	d
151.44	-76.24	LHD0470B.112	pr
154.36	83.95	LHD6979R.244	p
155.35	83.91	LHD5605R.112	dp
156.86	83.25	LHD5564R.243	f
159.68	-78.18	LHD0343B.109	pr
164.46	76.18	LHD4993Q.240	rf
164.51	81.34	LHD5173R.240	fd
166.93	89.03	LHD5643R.114	dr
167.15	80.91	LHD5286R.239	f
169.86	81.35	LHD5175R.238	d
169.87	79.18	LHD5107Q.238	dr
171.02	-81.44	LHD0095A.238	p
179.43	**89.72**	**LHD5696R.248**	**fp**
190.15	-77.39	LHD0469B.098	rf
191.53	83.32	LHD5417R.230	pr
191.54	**83.21**	**LHD5416R.230**	**r**
192.67	-80.56	LHD0308A.097	r
192.83	**-81.40**	**LHD0096A.230**	**dr**
192.90	**-76.89**	**LHD0392B.097**	**f**
197.24	89.46	LHD5611R.108	drf
200.20	78.82	LHD5279Q.227	dr
224.67	-76.57	LHD0421B.085	dr
224.72	-86.21	LHD0175A.083	r
229.10	-80.45	LHD0316A.083	p
230.32	-83.27	LHD0516A.082	pd
232.01	**-76.20**	**LHD0210B.215**	**f**
232.08	86.83	LHD5588R.217	fr
242.82	87.26	LHD5629R.214	df
243.37	82.05	LHD5628R.080	dr
244.03	-81.12	LHD0146A.210	d
244.99	85.05	LHD7605R.344	r
246.08	**81.88**	**LHD7638R.343**	**fh**
246.21	-82.25	LHD0142A.209	dr
250.58	**-85.48**	**LHD0193A.073**	**r**
251.14	-82.54	LHD0140A.207	r
251.65	79.76	LHD5397Q.209	f
254.56	79.99	LHD5250Q.208	f
254.65	-80.58	LHD0148A.206	r
258.78	-77.45	LHD0558B.072	f

261.17	**86.87**	**LHD5466R.208**	**dr**
266.18	**-83.86**	**LHD0278A.068**	**r**
266.42	86.58	LHD5492R.206	dr
268.33	87.79	LHD5595R.207	fp
269.63	**85.11**	**LHD5650R.072**	**d**
269.77	87.47	LHD5521R.206	dr
272.70	**82.72**	**LHD5562R.202**	**r**
273.41	79.55	LHD5545Q.069	d
273.56	79.74	LHD5547Q.069	d
281.47	-82.36	LHD0273A.063	fd
284.08	87.80	LHD5717R.202	dr
289.90	-80.94	LHD0149A.193	d
290.49	87.58	LHD5661R.068	d
291.22	-75.94	LHD0211B.193	d
292.29	77.16	LHD5116Q.194	d
292.30	77.07	LHD5110Q.194	d
293.74	-80.73	LHD0315A.059	p
296.28	-79.60	LHD0173B.191	dr
297.82	84.15	LHD5528R.193	dr
300.02	**79.68**	**LHD5345Q.059**	**hd**
300.98	80.42	LHD5441R.191	d
301.21	80.96	LHD5456R.191	dr
301.28	**85.55**	**LHD6749R.318**	**r**
301.55	-86.03	LHD0082A.320	h
301.58	-88.19	LHD0119A.052	r
306.10	**-77.54**	**LHD0387B.055**	**dr**
311.45	86.05	LHD6158R.320	rh
312.61	77.97	LHD5576Q.054	dr
312.73	78.18	LHD5578Q.054	dr
312.75	78.38	LHD5579Q.054	dr
314.96	77.38	LHD5307Q.053	dr
315.05	77.60	LHD5313Q.053	d
315.37	77.84	LHD5314Q.053	d
318.16	79.39	LHD5862Q.316	fdr
320.67	79.28	LHD5916Q.315	dr
323.28	86.62	LHD5574R.052	f
329.05	-78.41	LHD0362B.047	fd
338.05	86.90	LHD5972R.308	d
341.12	81.88	LHA3621R.307	dr
349.97	87.33	LHD5752R.303	pr
351.42	85.96	LHD5165R.171	r

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