ANALYSIS OF THE MARTIAN CANAL NETWORK

WELLS ALAN WEBB
San Francisco, California

The history of Martian observation and interpretation has been characterized by a schism that began in 1877 when Schiaparelli announced the discovery of many narrow dark streaks—canals—upon the surface of the planet, and others denied that such canals existed. The schism was broadened in 1894 when Percival Lowell announced that the canals made a system covering the whole face of the planet. Many other astronomers, who were unable to see the canals with larger telescopes, thought that Lowell in his enthusiasm was pursuing an illusion.

R. J. Trumpler, at the oppositions of 1924 and 1926, made many hundreds of Martian photographs showing canals, and by a system of combining negatives prepared a chart of Mars[1] that closely resembles Lowell's and Schiaparelli's charts.[2] Though Trumpler denies previous detailed knowledge of the latter charts, opponents of the canal theory hold that he was influenced by them in the preparation of his own.

Edison Pettit[3] confirmed the existence of the canals in 1939 and became convinced that they were as numerous as those represented on Schiaparelli's map of Mars. Like Trumpler, he also delayed comparison of his drawings with other charts of Mars until the opposition was past and his own drawings had been prepared for publication.

Many hypotheses have been advanced to explain the Martian canals in a natural way. Thus it has been supposed that they arose as the results of meteor falls; that they are volcanic in origin; that they are river beds or earthquake faults widened by erosion and overgrown with vegetation or filled with a deliquescent color-changing salt. But each of these theories becomes strained by attempts to use it to explain the observed network. Meteor falls, if they could produce a canal network on Mars, should do the same on the equally exposed moon, but despite the fact that several remarkably straight rays can be seen, no comprehensive network of rays has been observed there. The river-bed hypothesis and D. B. McLaughlin's very interesting theory that changes arose on Mars as a result of volcanism, and that ash is spread by seasonal winds along trails showing the Coriolis effect,[4] can hardly explain the canals because 94 percent of the lines of the canal network proceed unerringly from their beginning to another center point, and each of these points is the origin of from three to eight such connecting rays. A clue to the mystery of Mars may lie in the analysis and classification of its network pattern.

ANALYSIS OF THE NETWORK PATTERN

Neither Schiaparelli[2] nor Lowell[5] analyzed the extensive canal network that they so clearly defined in their drawings. W. H. Pickering, in his book *Mars*,[6] gives several illustrations of networks lying on the earth's surface that resemble the Martian type, but he does not apply mathematics to prove similarity or dissimilarity.[7] The application of the following analytical method to the network of Mars I believe to be new.

A surface network is composed of a primary point set distributed over the surface, with at least three radiant lines connecting every point with three other points of the set. A given point may be connected to more than three other points, the limit of such connections being the number of points in the point set minus one. No point is called a point of the network if it is connected to fewer than three other points, because a point connected to only two primary points is topologically indistinguishable from any other point in the connecting lines, and a point connected by only one line to a primary point is an unenmeshed appendage. In the process of connecting every primary point to three or more other primary points, other lines of the mesh are intersected, giving accidental definition to new points.

From the empirical point of view, networks have certain characteristics. In a communication network, for example, the accidental points may, as a rule, be distinguished by the fact that the two intersecting lines that define every such point do not abruptly change direction at the intersection. While the primary points are defined, as a rule, in advance of the construction of the network, and they may be marked by distinguishing circles, squares, etc., that appear in the pattern, they are also characterized by the fact that few (if any) lines pass through them without changing direction.

Again, from the empirical point of view, curved connecting lines or bands are topologically equivalent to straight, narrow connecting lines, provided the curved lines or bands do not involve additional points; and dotted lines are as effective as continuous lines for defining the mesh, provided the distance between dots does not cause confusion about the continuity and direction of the indicated line.

A certain curved line may define more or fewer accidental points than some other line that connects the same pair of primary points. The complete network is thus composed of the primary point set, the connecting lines, and the accidental point set. In discussing practical networks, we shall call the points junctions, and the connecting lines rays or canals.

Out of any point set, a great variety of networks may be constructed, depending upon the manner in which individual points are connected. A convenient statistical method for classifying networks according to type consists in counting and calculating the percentage of lines in the pattern that radiate from junctions having respectively three, four, five, etc., connecting rays. It is found that network patterns of nature and artifice thus analyzed fall into different groups.

Trumpler's map,[1] drawn from visual photographic observations during the oppositions of 1924 and 1926, is a remarkably clear description of the Martian surface markings and is in close agreement with the observations of others.[3,8,9] Changes of minor details occur from year to year, but observation has shown repeatedly that a detail lost by change is replaced by another of similar character; I believe, therefore, that conclusions drawn about a map of 1926 are valid today. Trumpler lists longitudes and latitudes of 228 points in his Table 6, and his Plates III and IV show how they are arranged in projections of Mars. I selected 158 points which Trumpler reports as marked by dark spots (oases); these constitute junctions from which three or more canals radiate to other junctions of the same group. These junctions will be called the primary point set; the accidental point set

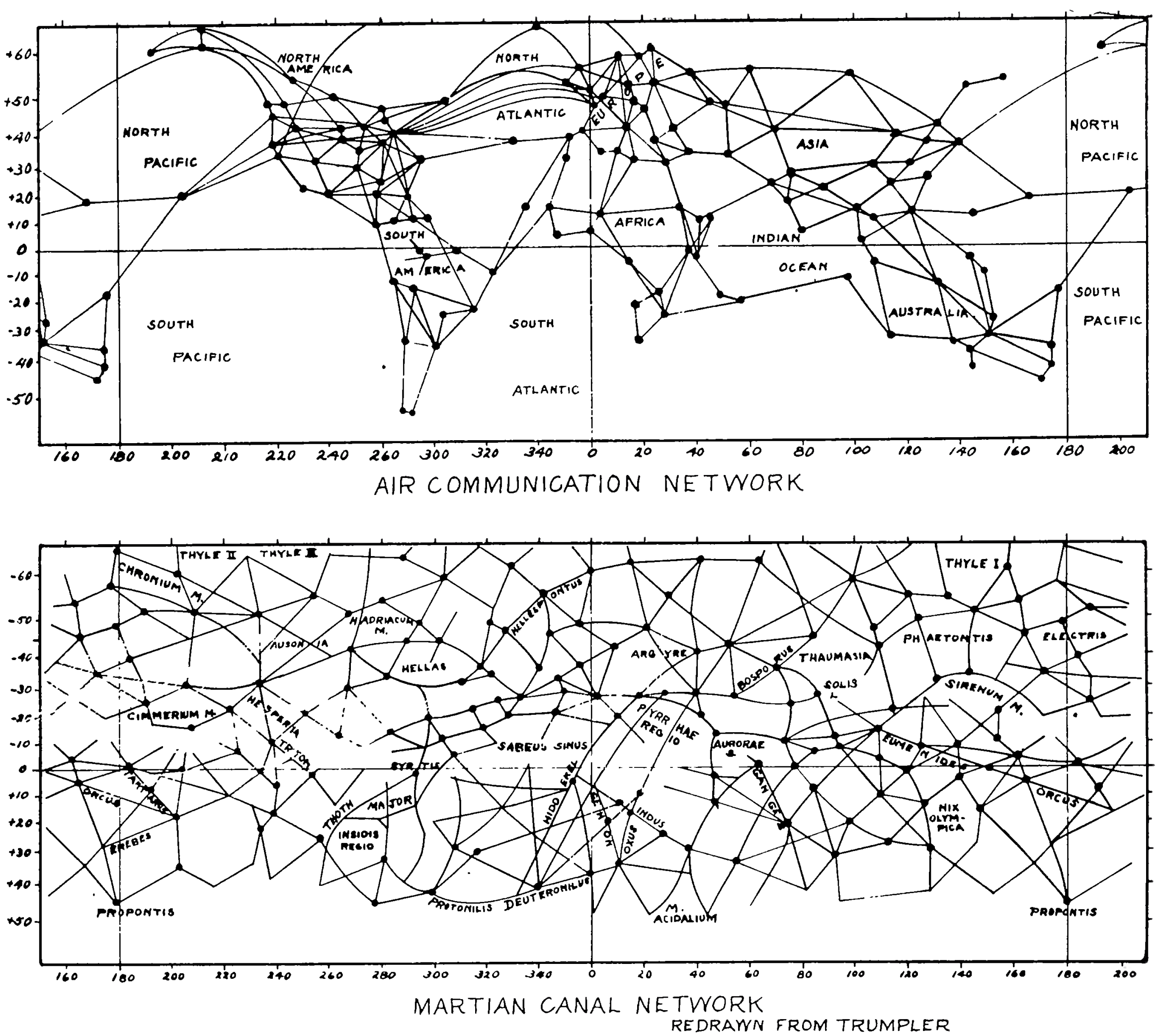
AIR COMMUNICATION NETWORK
NORTH PACIFIC
SOUTH PACIFIC
NORTH AMERICA
SOUTH AMERICA
NORTH ATLANTIC
SOUTH ATLANTIC
EUROPE
AFRICA
ASIA
INDIAN OCEAN
AUSTRALIA
MARTIAN CANAL NETWORK
REDRAWN FROM TRUMPLER
THYLE I
THYLE II
CHRONIUM M.
HADRIACUM M.
AUSONIA
HELLAS
ARGYRE
BOSPORUS
THAUMASIA
SOLIS L.
PHAETONTIS
ELECTRIS
SIRENUM M.
CIMMERIUM M.
HESPERIA
TRITON
SABEUS SINUS
PYRRHAE REGIO
AURORAE
EUMENIDES
SYRTIS
TOTH
MAJOR
INSIDIS REGIO
NIX OLYMPICA
ORCUS
EREBES
PROPONTIS
PROTONILIS
DEUTERONILUS
INDUS
OXUS
M. ACIDALIUM

FIG. 1.

is established by intersections of lines from the primary points. In Figure 1 all of the points of the Martian point set that appear are marked by dots, and the accidental points are unemphasized intersections. The few points of the point set not shown in Figure 1 appear in Trumpler's chart of the south polar region. Table I gives the tally of rays that go out from the primary and the

TABLE I

ANALYSIS OF THE MARTIAN NETWORK

Canals per Junction	Primary Junctions (Oases)	Accidental Junctions	Total Junctions	Total Canals	Percentage Distribution of Canals Among Junctions
1	0	22	22	22	2.1
2	0	0	0	0	0
3	40	13	53	159	15.4
4	53	58	111	444	43.0
5	37	5	42	210	20.3
6	18	3	21	126	12.2
7	9	0	9	63	6.1
8	1	0	1	8	.8
	158	101	259	1032	99.9

accidental points, and it also gives the percentage distribution of rays among classified points of the network.

In the tabulation of primary points, it is seen that the largest number have four canals connecting with other primary points. A somewhat smaller number of junctions have either three or five connecting canals, and a still smaller number have up to eight. As was to be expected, the majority of accidental points, being defined by the chance crossing of connectors for the primary point set, are points from which four lines radiate. A few accidental points possessing five and six rays are defined by the chance overlapping of band canals. Twenty-two rays from primary points were counted which ended at points not in the network; these solitary end-points are listed for convenience under accidental points. The proportion to the total number of points which these non-network points bear is an index to the degree to which the whole pattern is a network. It is possible, of course, that some or all of these twenty-two points are connected by other existing canals which were not sufficiently well seen by Trumpler for definition. Thirteen points that have three rays are listed as accidentals because they were not marked by a dark area.

When every sum of accidental points is added to the sum of primary points which possess the same number of rays, and the percentage distribution of rays among all points is calculated, a statistical curve is arrived at which reveals characteristics of the Martian network in a form suitable for comparison with other networks.

IDENTIFICATION OF THE PATTERN

We see in Table I that approximately 15 percent of the canals in the Martian network as Trumpler has defined it[1] pass out of junctions of three canals, 43 percent of the canals in the network pass out of junctions of four canals, 20 percent out of junctions of five canals, 12 percent out of junctions of six canals, 6 percent out of junctions of seven canals, and there is one junction in the network with eight canals. With this analysis in the background, let us look at other network patterns that resemble this in their analyses. We shall consider first typical examples of natural networks without regard to size or visibility.

An irregular quadrilateral pattern is seen in any system of shrinkage cracks. Because this is an obvious geological configuration frequently speculated upon in connection with Mars, we undertook to study it. The shrinkage crack pattern is encountered most commonly on mud flats. The clay ground of California's Imperial Valley is prolific in the production of this pattern and a count reveals that its topological characteristics are identical with the cracks in lava rock; they do not, however, coincide with the Martian network, for reasons to be set forth in the following paragraphs.

Lava rocks are relevant to our argument, for some writers have said that the canals of Mars are shrinkage cracks formed in an initially homogeneous covering of solidified lava. Some cliffs and rock islands off the beach just north of Carmel, California, are composed of this material. I have counted the number of cracks that proceed from the various points in the point set that appears on the surfaces of these formations in order to work out the percentages of rays that originate in points from which three, four, five, etc., cracks radiate.

It is clear from Table II that the size of the cracks considered does not materially affect the proportions. Whether small fissures in the lava or large fissures were counted, the result is substantially the same. Not knowing where to locate cracks larger than twenty feet, I went to the small extreme to confirm effect of size on pattern. This can be found, for example, in the crazed glaze of chinaware. A beautiful illustration of a small vase tesselated with shrinkage cracks appears in *Encyclopaedia Britannica* (1952), **18**, 355. Rays from points in this pattern were counted and the tally entered in Table II.

When we compare the three kinds of shrinkage patterns, we see that they are approximately alike in that, of the total number of rays in the pattern, the percentage that originate at points from each of which only one ray passes out, is very small. This fact shows that the pattern is a true network. The shrinkage network, as we see it from these examples, is characterized by the emanation of from 71 percent to 78 percent of the rays of the pattern from points having three rays. From 24 percent to 21 percent of the rays emanate from points having four rays and a very small remainder emanate from points having five to seven rays.

Again, this cannot be the type of pattern that we see on Mars, for the latter has a relatively small percentage of rays emanating from points having three rays and a relatively large percentage of rays emanating from points having four or more rays. The Martian pattern is thus very complex.

Despite the comparative simplicity of the shrinkage pattern, I doubt that we are likely to encounter, on a microscopic scale in inanimate nature, a pattern of greater complexity. Let us then leave our consideration of works of inanimate nature and proceed to consideration of patterns produced by the purposeful action of certain animals. We see, for example, in the spider's web (as analyzed in Table II) a network in which a preponderance of the rays of the pattern emanate from points having four

TABLE II

DISTRIBUTION OF RAYS AMONG POINTS IN TYPICAL NETWORK PATTERNS, EXPRESSED IN PERCENT

	Shrinkage Cracks			Patterns of Purpose				Canals of Mars	
		Lava Rocks		Webs of Spiders		Railroads			
Rays per Point	Vase Cracks in Glaze (a)	Small Fissures (b)	Large Fissures (c)	Argiopid (d)	Epeirid (d)	Iowa (e)	Ohio (e)	Trumpler (f)	Lowell (g)
1	0.6	2.7	.8	1.4	.3	1.0	1.4	8.2	3.7
3	77.5	72.0	71.8	0	5.1	24.9	10.9	20.5	12.5
4	21.5	22.2	23.9	97.2	92.2	49.9	47.2	42.9	54.7
5	0.4	1.8	2.3	0	.9	10.1	13.7	16.3	7.0
6	0	.6	.8	0	.5	7.5	9.0	8.2	5.8
7	0	.6	.4	0	0	3.4	5.8	3.5	5.2
8 or more	0	0	0	1.4	1.0	3.2	12.0	0.4	11.1

(a) *Encyclopaedia Britannica* (1952), **18**, 355.
(b) Cracks from six inches to two feet long.
(c) Cracks from two feet to twenty feet long.
(d) *Encyclopaedia Britannica* (1954), **21**, 215A.
(e) From map supplied by Southern Pacific Company.
(f) Lick Observatory Bulletin No. 387, 1927.
(g) Percival Lowell, *Mars and Its Canals* (New York: The Macmillan Company, 1908). In making this tabulation, it was assumed that canals running into dark areas on Lowell's map (pages 384–85) were continuous and did not end at a dark area.

rays and in which more than a dozen rays emanate from the center point of the pattern.

When we inquire what factor entered that gave the spider's web its predominantly four-way pattern, we understand at once that this pattern came as the result of utilitarian design—i.e., that the web is the most efficient possible food trap, developed over successive spider generations until at last it became lodged permanently among the spider's instincts. The spider is not capable of simultaneously constructing several connected webs having centers from which many lines radiate to other centers, in the manner that we observe on Mars. One center having many radiant lines is the spider's "intellectual" limit, though this may be combined with another structure of a different type, such as a shelter or hideaway. Thus, inherited intelligence produced a pattern of purpose which we see is characterized by the fact that a preponderance of the points have four rays—one more ray per point than is typical of the shrinkage network pattern of inanimate nature.

COMMUNICATION NETWORK PATTERNS

For a network pattern of a larger number of rays per point and greater complexity, we can look at one that covers the earth's surface as an inevitable consequence of man's activities. This is the communication network, a natural pattern that arose first in footpaths from village to village, and became more and more complex with shifts in population and improvements in transportation and communication. Today one sees this network on every map of an inhabited country. It is especially apparent on railroad maps and maps of commercial airplane routes (see Fig. 1).

For purposes of analysis, I have selected railroad communication patterns, a type easily visible from above, and I have classified the junctions according to the number of lines diverging from each. Table II shows that the railroads of Iowa, a rural area, present a pattern characterized by a minority of lines emerging from junctions of three lines, a plurality of lines emerging from junctions of four lines, and a substantial proportion of the lines emerging from junctions of five, six, and more lines. In Ohio, a more industrial area, we see that proportionately fewer lines emerge from junctions of three and four lines, and proportionately more emerge from junctions of five and more lines. Why this is so is, of course, clear: as settlement increases, more and more lines of communication emerge from the most populated centers.

To recapitulate: in the microscopic networks of inanimate nature, the majority of rays emerge from points having three rays; in networks constructed by an intelligence of a low order (e.g., the spider) only a small portion of the rays emerge from points having three rays, and by far the most rays emerge from points having four rays; in networks constructed by an intelligence of a high order, a substantial proportion of the rays emerge from points having four rays, and many points in the pattern have more than four rays.

In Table II, we see that the communication networks, as exemplified by the railroads of Iowa and Ohio, are strikingly similar in their analysis to the Martian canal network. We see that Trumpler,[1] in recording only the darkest canals, produced a map of Mars whose network characteristics resemble those of rural Iowa, while Lowell,[10] in recording all that he could surely see, whether faint or well defined, produced a network whose characteristics are most like those of industrial Ohio.

Although the Martian network appears to be clearly of the communication type, I do not wish to imply that it has been proved to have a design requiring intelligence equal to man's for its creation. Additional evidence giving more certain criteria for patterns indicating high intelligence is required before such a hypothesis can be proposed.

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[1] *L.O.B.*, No. 387, 1927.

[2] *G. V. Schiaparelli*, Smithsonian Inst. Report, 1894, p. 113, tr. by W. H. Pickering; Percival Lowell, *Pop. Astron.*, **2**, 1, 1894.

[3] *Pub. A.S.P.*, **59**, 5, 1947.

[4] *Pub. A.S.P.*, **66**, 161, 221, 1954.

[5] *Lowell Obs. Annals*, **3**, 268, 1905.

[6] W. H. Pickering, *Mars* (Gorham Press, Boston, 1921).

[7] W. W. Campbell, *Pub. A.S.P.*, **30**, 133, 1918.

[8] Jarry-Desloges Obs., *Observations*, **1–10**, 1907–41.

[9] Bernard Lyot, *L'Astronomie*, **57**, 49, 67, 1943; *Ap.J.*, **101**, 255, 1945.

[10] *Mars and Its Canals* (Macmillan, 1908).