Indian Journal of History of Science, 17 (1) ; 1—17

TIEFFENTHALER ON LATITUDES AND LONGITUDES IN INDIA— AN EIGHTEENTH CENTURY STUDY OF GEOGRAPHICAL COORDINATES

S. N. SEN

Ramakrishna Mission Palli, P.O. Narendrapur
24 Parganas 743 508

In the eighteenth century the pioneering efforts of reconstructing the geography of India along scientific lines were handicapped by the paucity of data on geographical latitudes and longitudes, particularly the latter, and, where available, by their unreliability. The situation was further confused by the lack of a uniform standard of measuring distances. Not only did the measure of the Indian mile vary from that of its European counterparts, the Indian measure itself varied from region to region. In the absence of astronomically determined geographical latitudes and longitudes of a large enough number of places and dependable land surveys, what assumed without doubt of considerable importance were the itineraries, route-mileage and army marches found in the various Persian and Indian historical-geographical tracts, provided one was able to rationalize the varying measures of length used in such texts. D'Anville made a remarkable use of these indigenous materials for reconstructing his maps of surprising accuracy and Rennell, who had the advantage of making his own survey with the assistance of his own able team of surveyors, used them no less. Tieffenthaler, like D'Anville, not only endeavoured to make the most of the materials of the Persian and Indian geographers, but undertook to improve upon the existing tables of latitudes and longitudes by determining them himself in the course of his extensive travels in the country. Considerable importance therefore attaches to the first six chapters of his dissertation on preliminary researches of his *Geography of Hindustan*[1] where he discussed the materials on latitudes and longitudes collected from historical sources and travellers' accounts, the varying measures of the Indian mile, the paucity of data, his own efforts and suggestions for improving upon the cartography of India.

THE EXTENSION OF INDIA

From one end of the Ganges to the other, India, states Tieffenthaler, is a very vast country, extending less in breadth than in length, tapering to a point on the south and dilating on the north. But how vast is this extension in geographical latitude and longitude? In latitude, one measures the extension by about 30 degrees from Cape Comorin to the frontiers of Kabul province, or equivalent of 450 German

miles at the rate of 15 miles to the degree.[2] It is not difficult, he observes, to verify or ascertain more correctly this latitude difference, for, the latitude of Cape Comorin being already known with accuracy, one has only to observe the meridian latitude of the sun at Kabul. 'Quant à la Latitude, il suffiroit pour en connoitre la difference entre la limite la plus septentrionale et la plus méridionale, qu'un observateur prit des hauteurs méridiennes du Soleil à *Kaboul:* car la hauteur du pôle au Cap *Comorin* est déjà connue'.[3]

The latitudes of the regions occupied by the Hindukush mountains on the northern borders of India were regarded to be in the neighbourhood of not less than 38°. As to the well known latitude of Cape Comorin which he does not quote in the *Geography*, Tieffenthaler probably had in mind the values, 8° approximately, given by Pimentel, Fathers Thomas and Bouchet.[4]

The extension in longitude from east to west, that is from the confines (of the eastern borders) of Tibet to the Indus, was, however, a matter of guess in the absence of the required longitude determinations either by the astronomers or by the surveyors. The easternmost point for which longitude was known with good degree of accuracy was Chandernagor, the French Colony, in Bengal. Father Claude Boudier, Jesuit missionary had determined its longitude from a series of observations to be 105°53′ reckoned from the prime meridian of Ferro in the Fortunate Islands (Madiera Islands and Canary Islands).[5] But nothing definite was known with regard to Chittagong (*Schatigan*), the eastern limit of India. About this important eastern limit in Indian cartography, D'Anville, while reporting fairly accurately on its latitude (about 22°20′) on the basis of observations of Pimentel and Father Barbier, was unable to say anything about its longitude.[6] Rennell states that charts published as late as 1752 gave the difference of longitudes between Balasore and Chittagong as 3°48′ as against 4°53′ determined in his time by the marine survey of Capt. Ritchie, a difference of 1°5′ which 'gave the sea coast between the mouths of the Ganges, a direction of two points, or 22½ degrees more northwardly than the truth; which doubtless occasioned the loss of many ships, who trusted to the information'.[7]

Even here Tieffenthaler, on the basis of information contained in a Latin geographical dictionary, *Lexicon geographicum* by Philippe Ferrari (Milan, 1627), was able to work out the longitude difference between the mouths of the two arms of the Ganges falling into the sea (the Bay of Bengal) to be 4°15′.[8] This value approximately representing the longitude difference between Chandernagor and Chittagong is not far removed from the one determined by Ritchie's survey.

As to the longitude of a westernmost point, say Sindh or Tatta, the situation was still more indefinite; for although Tieffenthaler himself determined the longitude of Surat from an occultation of the Jupiter by the moon, this determination was hardly of any use for the purpose as there was no way of ascertaining longitude difference between Surat and Sindh or Tatta.

This uncertainty in India's extension in longitude in the mid-eighteenth century is also reflected in the existing maps,—some of them quite well known, to which Tieffenthaler drew attention. Thus, 'la Carte générale de I'Asie publiée dernierement en Angleterre', referring probably to Jefferys' map, gave the longitude of the western limit as 65°, that of Chittagong, the eastern limit as 90° and the extension of India in longitude as 25°. Another map, possibly, Jefferys' *The East Indies with the Roads* (1768) gave the aforesaid limits at 67° and 91° respectively, making the longitude difference to be 24°. A Dutch map (published by Schenk and Valk) indicated this difference as 26°, while a Nuremberg map *Indes Orientales* edited by Tob-Mayer after M.d'Après de Mannevillette (published by Homann, 1748) put it down to 24°. On the face of such divergent views India's extension in longitude appeared to Tieffenthaler to lie near 25° or 375 German miles.[9]

The position of a large number of places likewise suffered from a great deal of uncertainty. Inspite of his determinations of latitudes of several places, there had still remained, complained Tieffenthaler, a very large number of cities of which no attempt had been made to find the latitudes either by an astrolabe or by any other suitable astronomical instrument. The knowledge of longitudes of places was still worse, for it was difficult to assure anything about most of the places in India with the exception of a handful of cities, such as Agra, Narwar and Fyzabad, of which longitudes were determined by the eclipses of the moon[10]. Tieffenthaler laid great emphasis on the latitude and longitude determination for the development of an accurate geography of India and stated that for resolving such fundamental points as the western and the eastern limits of India an easy method would be to have a solar or a lunar eclipse observed simultaneously by two astronomical observers one stationed at Tatta and the other at Chittagong.

> "Un moyen facile de determiner ce point seroit que deux Astronomes observassent une éclipse de Solei ou de Lune, l'un à *Tatta*, l'autre à *Schatigan*. On déduiroit aisément de ces deux observations la différence en longitude géographique."[11]

In the eighteenth century there was of course no special merit in such a proposal from one versed in astronomy, but the real problem was one of organizing such simultaneous observations of infrequent natural phenomenon like the eclipses of the sun, moon or the Jupiter's satellites. For the longitudes Rennell had to depend generally on his traverse measurements, but his excessive reliance on them uncorroborated by parallel astronomical observations sometimes drew sharp criticisms from men like Dalrymple[12] and Reuben Burrow. "The Surveys of India", wrote Burrow in one of his proposals submitted to Warren Hastings in 1783, "are known to be remarkably defective and there is great reason to believe that not a single place in India has had its Longitude properly determined except Pondicherry. The Latitudes are nearly in the same predicament, and indeed most of the English maps are made up of ideal chains of mountains and imaginary woods, taken piecemeal by pretended

surveyors, and put together at random without either Longitude or Latitude,..... and geography is so little benefitted by such maps that they are a nuisance rather than an advantage....."[13]

How much worse the position in this regard must have been forty years back when Tieffenthaler first started his work can be easily understood from the above observation from one who was himself an accomplished astronomer and mathematician[14].

Data on Latitudes and Longitudes from the Works of Oriental Geographers and Foreign Travellers

Tieffenthaler then discussed in chapters II to VI the data on latitudes and longitudes he was able to collect from oriental sources, Indian as well as Persian, and from accounts by some European travellers and geographers, the route mileages from the *'Āin*, and the varying measures of the Indian mile. Much of these materials as well as those concerning references to India in ancient texts in the subsequent chapters are only of historical importance; and it is well that he has treated these materials separately instead of scattering them throughout the text in association with the places concerned as did D'Anville in his *Êclaircissemens* or Rennell in his *Memoir*.

One is struck by his opening remark that the Indian geographers made no mention of either of any determination of latitudes by the meridian altitudes of the sun or that of longitudes by the eclipses of the sun and the moon, and that they came to know of these (methods) from the (foreign) travellers[15]. Granting that Tieffenthaler did not know enough Sanskrit to consult Indian astronomical texts on this point, it is not easily understandable how he could have ignored the information already contained in the *'Āin* upon which he drew so extensively. On terrestrial longitudes, the *'Āin* informs us:

> "The Hindus term longitude *lambana*, and make it consist of 180° after the manner of the Greeks. They reckon its beginning (as 0° of longitude) from *Yamakoti* in the farthest east, apparently because following the movement of night and day, the nearest point to its origin is selected....."
> "*To find the longitude*; at the first meridian or a place whose longitude is known, observe the exact time of the occultation of light in a lunar-eclipse, its duration and initial or total reappearance, and let a similar observation be made at the place whose unknown longitude is required. If the time be the same on both, their longitude will be the same. If the time be later at the place required, the city is more to the eastward. The difference of the times of observation is taken, and an excess in the number of degrees over the place whose longitude is known, is allotted on the calculation of six degrees for every ghari and fifteen degrees for every hour, reckoning 4 minutes to the degree. If the time be earlier, the city is more westerly and the calculation is the reverse

> of that for the east. According to the system of the Hindu astronomers who begin their reckoning of longitude from the east, in the first instance, the number of degrees will diminish, and in the second case, increase."[16]

Elsewhere the *'Āin* gives further practical details of longitude measurements by the Indians:

> "Also on a level plain at sunrise they regulate the course of *gharis* by means of the *siktajantra* which is an instrument like an hour-glass, measured for 60 *gharis*. With this they walk eastwards. After 84 *yojanas* and a fraction, there is a difference of one *ghari* and the day advanced *by that* time. This multiplied by 60 gives the circumference of the Earth."[17]

The principle of the method, as Reuben Burrow pointed out, was the same as that of the longitude watches in use during the 18th century.

The *'Āin* has likewise given a fairly good account of the Hindu method of finding terrestrial latitudes. "This is called by the Hindus *Aksha*. It is reckoned from Lanka ....," records *'Āin*. Then, after defining the latitude and stating that it is the same as 'the degree of the elevation of the pole (above the horizon of the place)', three methods of finding the latitudes are described, e.g. (1) the method of circumpolar star, (2) the method of the sun's meridian altitude at the equinoxes, and (3) the method of the sun's meridian altitude at the solstices.[18] Al-Bīrūnī has quoted the latitudes of a few places, determined by the Hindus in ancient times, and generally accepted among the Hindu astronomical circles throughout India. He informs us that 'all the canons of the Hindus agree in this, that the latitude of Ujain is 24 degrees, and that the sun culminates over it at the time of the summer solstice'.[19] Furthermore, "Balabhadra, the commentator, gives as the latitude of Kanoj 26°35′; as that of Tāneshar 30°12′..... According to the book *Karaṇa-Sāra*, the latitude of Kashmir is 34°9′, and the straight shadow there 8 $\frac{7}{60}$ digits.'[20]

Even in Tieffenthaler's own time Indian geographer and surveyors here and there were doing good work. Rennell informs us of 'a Bramin of uncommon genius and knowledge, named Sadanund' who had prepared a highly informative map of the peninsula of Gujarat. 'This genuine Hindoo map', writes Rennell, 'contains much new matter: and the Ayin-Acbaree assists in discriminating the valuable parts of it. In it is found the site of Mahmoodabad; in its turn, the capital of Guzerat and founded by Sultan Mahmood in the 11th Century. The Ayin-Acbaree describes the walls of it, as including a vast extent of ground; and speaking of it rather as an existing city, than as a place in ruins. This was in the latter part of the 16th century. Junagur, or Chunagur, a city and fortress in the heart of the peninsula, and a subject of Ferishta's history; together with many other positions, are pointed out, or illustrated, by this map; which, as we have said before, is the production of a native of Guzerat. Without a particular account of its author, one might have rested satisfied with its containing

a great variety of particulars, although not arranged in geographical order; but it is remarkable, that it gives the form of Guzerat with more accuracy, than the European maps could boast of',[21] Tieffenthaler himself employed a trained Indian geographer to explore the source of the Gogra up to the cataract.[22]

Unable to find in Indian works any method for the determination of latitudes and longitudes or values of these geographical elements, Tieffenthaler gives an idea as to what the Indians thought about the extensions of their country east-west and north-south. The east-west extension, or longitude difference in mileage, from Bihar to Gasni was thought to be 1,511 Indian miles; the latitude difference, also in mileage, between Sholapur and Little Tibet, to be 1,176 miles. According to another manner of calculation, starting from Delhi, capital of India one estimated 975 miles up to the south-eastern limits; 535 miles up to south-western limits; 600 miles up to the fortress of Sholapur in the south; and 577 miles up to the northern limits, that is to say, up to Little Tibet. The north-south extension differs only by a mile in the two reckonings. It may further be noted that India Tieffenthaler proposed to describe did not extend beyond Sholapur in the south and therefore comprised territories known under the name of Hindustan in medieval times.

First Meridian for Reckoning Longitudes

Tieffenthaler, however, found more information when he turned to Persian and Arabic sources. In presenting tables of latitudes and longitudes of a number of places in India, drawn from Persian and Arabic works, he explained that the longitudes reproduced all referred to the first meridian passing through the Fortunate Islands. In this the Arabs and the Persians followed Ptolemy who had imagined his first meridian to pass through the island of *Ombrio* and *Pluvialia* or better *Pluitalia*[23]. The values of European geographers of his time and those of his own given in the book were generally calculated from the prime meridian of Ferro (Méridian de l'Isle de Fer), whereas those of Father Claude Boudier were with regard to Paris. In English geographical works, longitudes were given with regard to the meridian of Greenwich. To understand the agreement or otherwise among these values collected from different sources, it is necessary to reduce all longitude values to one particular meridian of reference,—a task which Tieffenthaler himself should have done. This is all the more unavoidable because, in the first place, opinion differed as to the position of the prime meridian of Ferro to which Tieffenthaler drew attention,[24] and, in the second place, the meridian of Ferro, albeit supposed to be in the Fortunate Islands (Madeira and Canary islands) was not the same as that of the Fortunate Islands from which the longitudes of the oriental geographers were reckoned. Their difference in longitudes as the following would indicate is indeed considerable.

D'Anville placed the first meridian 20 degrees west of Paris and gave the longitude of Agra, determined by Fathers Claude Boudier and Gaubil, as 75°45′ with regard to Paris and 95°45′ from the first meridian[25]. Rennell quotes Boudier's value

reduced to the meridian of Greenwich as 78°29′[26]. This makes the longitude difference between Paris and Greenwich as 2°44′ and the longitude of the prime meridian of Ferro 17°16′ west of Greenwich. For Delhi, Boudier's values with respect to the meridian of Ferro and Paris are 94°54′[27] and 74°54′ respectively, and Rennell gives 77°40′ with respect to Greenwich[28], from which the longitude difference between Paris and Greenwich works out to 2°46′ and the longitude of the meridian of Ferro 17°14′ W. For Chandernagor, D'Anville records Boudier's value with regard to Paris as 86°5′[29] which Tieffenthaler expresses as 105°56′[30] with regard to the meridian of Ferro, making the longitude difference between Paris and the meridian of Ferro as 19°51′ in close conformity with D'Anville's round figure of 20°. In transforming all longitude values given with respect to either Paris or the meridian of Ferro to those with respect to the meridian of Greenwich, the longitudes of Paris and Ferro will be taken to be 2°45′ E and 17°15′ W respectively.

The longitude of the meridian of the Fortunate Islands from which the oriental tables of longitudes were constructed is more uncertain. I have followed Rennell in fixing it to be 35°30′ W of Greenwich as under:

By the tables of Ulug Beg and Nasir-uddin			By construction		Longitude of Fortunate Islands	
Canoj	115°50′	east of Fortunate Islands	80°16′	east of Greenwich	35°34′W	say 35°30′
Balk	101°00′	,, ,, ,,	65°31′	,, ,,	35°29′W	

Values of latitudes and longitudes quoted by Tieffenthaler from the works of oriental geographers, are reproduced in Table 1. For convenience of comparison, the corresponding values as given in the *'Ain*, the work most frequently consulted by him, have been added, as also some astrolabe values within parenthesis. It will be noticed that longitude values have been shown under two columns, the one giving values with reference to the meridian of the Fortunate Islands and the other the same values converted to that of Greenwich according to the method explained above. The places are given in descending order of latitudes.

Tieffenthaler's general criticism is that, although for some of the places these accord well with the correct values, for the majority of places these differ more or less from the true ones. The errors, however, are more pronounced in the case of longitudes. The following discussion will show that while in certain cases the criticism is valid, he generally underestimated the value of oriental tables which contained quite a large number of reliable determinations. He points out that the longitudes of Kabul and Delhi, for example, were given as 114°40′ and 113°25′ respectively, which would place Kabul east of Delhi[31], an impossible situation as there was no question of Delhi being east of Kabul. But here the mistake was Tieffenthaler's own for he wrongly quoted the longitude of Kabul, the correct value given in oriental tables being 104°40′. Elsewhere in the book where he discussed the geography of Kabul and Qandahar,

the longitude of Kabul is correctly given as 104°40′[32], and therefore his criticism of the oriental tables on this count seems rather baffling.

TABLE 1

Values of Latitudes and Longitudes given by Tieffenthaler from the works of Oriental Geographers

Name of Place	Quoted by Tieffenthaler from oriental geographers			From *'Āin* & Astrolabes (given within parenthesis)*			Modern Values	
	Latitudes	Longitudes		Lat.	Long.		Lat.	Long. (Greenwich)
		Meridian of Fortunate Islands	Converted to Greenwich Meridian		Fortunate Islands	Greenwich		
	deg min	deg min	deg min	deg min	deg min	deg min	deg min	deg min
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Kashmir (Srinagar)	35	108	72 30	35 (35)	— (108)	— (72 30)	34 36	74 30
Kabul	34 30 34 35	114 40 104 40	79 10 69 10	34 30 (34 30)	104 40 (104 40)	69 10 (69 10)	34 18	69 11
Kandahar	33 0	107 40	72 10	33 40 (33 0)	107 40 (107 40)	72 10 (72 10)	31 22	65 18
Ghazni	34 40 33 54	94 30 92 52	59 0 57 22	33 35 (33 35)	104 20 (104 20)	68 50 (68 50)	33 20	68 10
Lahor	31 51	—	—	31 50 (31 50)	109 22 (109 20)	73 52 (73 50)	31 20	74 22
Multan	28 40 29 50	107 35 108 0	72 05 72 30	29 52 (29 40)	107 35 (107 35)	72 05 (72 05)	30 7	71 19
Panipat	28 52	113 20	77 50	28 52 (28 52)	108 10 (113 20)	72 40 (77 50)	29 14	77 06
Delhi	28 39	113 25	77 55	28 15 (28 39)	114 38 (113 35)	79 08 (78 05)	28 23	77 07
Agra	26 43	115 0	79 30	26 43 (27 43)	115 0 (114 0)	79 30 (78 30)	27 06	78 30
Gwalior	26 29	—	—	26 29 (26 29)	115 0 (114 0)	79 30 (78 30)	26 08	78 06
Ajmer	26 0	111 05	75 35	26 0 (26 0)	111 05 (111 05)	75 35 (75 35)	26 16	74 25
Tatta	25 20 24 0	86 0[1] —	68 45 —	24 20 (25 10)	102 31 (102 30)	67 01 (67 0)	24 26	67 35
Aurangabad	20 8	—	—	23 15	108 30	73 0	19 32	75 14

*Based on astrolabes preserved at the Red Fort Museum, Indian Museum and G. R. Kaye's *The Astronomical Observatories of Jai Singh*; Nassiruddin & Ulug Beg's values are generally given.

[1]Supposed to be from the Islands of Ferro.

Even he was not satisfied with the value of latitude given in the oriental tables and considered it unreliable as he had no means of verifying it with modern determinations. He wrote that he did not know of any European versed in astronomy who had recently penetrated into these countries and used astronomical instruments for measuring latitudes from the Sun's meridian height. Moreover, there was considerable uncertainty in the knowledge of places in these regions and of their distances from one another, which rendered calculation of latitudes from route mileage a fruitless task. Nevertheless, on the basis of geographical information available, an ordinary traveller's coverage of 12 miles a day, and 38 or 40 Indian leagues to the degree, Tieffenthaler concluded that Kabul should be full 10 degrees north of Delhi, that is, over 38°, in agreement with the value of 39° assigned to Kabul in the Dutch maps of Messrs. Schenk and Valk. "Si donc on compte pour un degré 38 ou 40 lieues indiennes, lesquelles sont plus petites dans les contrées situées au Nordouest, on trouvera *Kabul* est de 10 degrés pleins plus au Nord que *Delhi*, ce qui s'accorde avec les cartes publiées à Amsterdam chez *Schenk* et *Valk*, qui donnent à *Kaboul* la latitude septentrionale de 39°."[33] Here Tieffenthaler, in his effort to justify European values, not only gave a figure far wide of the mark, but rejected the accurate values given by such eminent oriental astronomers as Nasir-uddin and Ulug Beg (modern values of Kabul: lat. 34°8′ N; long. 69°11′ E).

Quandahar's latitude of 33° is the value given in the tables of Nasir-uddin and Ulug Beg and differs from the *'Āin*'s. This and other discrepancies indicate that, although Tieffenthaler borrowed freely from the *'Āin*, he consulted other Persian and oriental tables as well. As to longitudes, he rightly pointed out that it could not be 107°40′ if that of Kabul which was north-east of it was 104°40′. He accepted Danet's value of 83°40′ (or 66°25′ E) which was much nearer the true value of 65°18′ E (see Table 3).

Nassir-uddin and Ulug Beg's table assigns Ghazni the latitude of 33°35′.[34] It is to be noted that with the exception of the latitude value 33°54′ which is near enough but not the same as Nasir-uddin's or *'Āin*'s, other values given by Tieffenthaler differ markedly. The sources of these values are not known; but whatever the sources these were undoubtedly much inferior to the *'Āin* or the table of Nasir-uddin and Ulug Beg when compared to the modern values: lat. 33°20′, long. 68°10′ E.

For Lahor's latitude, Tieffenthaler gave another value, 31°40′,[35] nearer the modern value 31°20′ N. Regarding the longitude, he did not quote from oriental tables, but, besides quoting Danet, gave another value 93°30′. Danet's value agrees better with the modern figure of 74°22′ E (Table 3).

The position of Multan was another debatable point. In addition to 28°40′, he quoted another oriental value 29°50′[36]. 28°40′ appears to be a copying error and represents Nasir-uddin's well known and oft-quoted value of 29°40′. Both these values appear to have been taken from the *'Āin*. But Tieffenthaler agreed with Danet

that Multan should be more to the north and thought fit to assign it the latitude 31°. As to longitude, he considered the values given in the oriental tables and by Danet a little too high and suggested 88°40′ or 71°25′ E with respect to Greenwich. Rennell analyzed all these historical materials including Tieffenthaler's observations and concluded its latitude to be 30°34′ and longitude 71°21′[37] (modern values: lat. 30°7′, long. 71°19′ E).

Tieffenthaler assigns to a place called *Baker* the latitude of 28°40′ and longitude 87°.[38] According to his statement, this place was formerly, called *Mansoura. Mansura* of the *'Āin*, was assigned lat. 26°40′ and long. 105° (69°30′ E). Tieffenthaler's longitude 87°, given most probably with respect to the meridian of Ferro, is equivalent to 69°45′ E from Greenwich and compares favourably with the value given in the *'Āin*, but he gives it a much higher latitude 2° more to the north, more or less in agreement with the value given by Manucci whom he generally ignores. D'Anville speaks of a place called Bukor, referred to as Peker by the Turkish geographers, to which he assigned the latitude of 28°.[39] As Baker was modern Sukkur (lat. 27°25′; long. 68°33′), Tieffenthaler's values still left much to be desired.

Regarding the latitude of Tatta, Tieffenthaler's preference for 25°20′[40] to 24°20′ (modern value 24°26′) was hardly any improvement. For longitude, his value of 86° (from Ferro) or 68°45′ E was a slight improvement upon the oriental value (modern value 67°35′ E).

Values for other places cited from oriental tables need not be considered, as Tieffenthaler either used his own direct measurements or used the values more recently taken by skilled astronomers like Father Boudier, to which we shall return later.

Manucci's[41] values are reproduced in Table 2. Nicholas Manucci (b. 1639), a Venetian adventurer and physician reached Surat in January 1655/56, served under Prince Dara Shikoh as an artillery man and later joined Aurangzeb's army. He practised medicine at Lahor, visited Hugli, widely travelled in India and spent the remainder of his life as a Company's servant between Madras and Pondicherri. The sources of his geographical information are not known. His values given with respect to Fortunate Islands are converted with respect to Greenwich. Values from *'Āin* and the modern values are also given for purposes of comparison. His longitude values differ widely from 7°42′ to 11°34′, with an average variation of 9°40′. This can be partly reconciled if Manucci assumed his prime meridian 45°10′ west of Greenwich. But did he really give his longitude values with respect to such a prime meridian? More importantly, his latitude values, where the scope for error is limited, also varied widely. Tieffenthaler's purpose in quoting these values from the correct ones was to show how some of the European travellers and scholars of note were negligent and careless about these essential geographical elements. But then he excused the Venetian physician who had naturally better knowledge of the art of medicine than that of geography and astronomy.

Not so was Danet, the French geographer whose latitude and longitude values reproduced in Table 3 conformed more or less to the correct values. Danet's latitude

values more or less agree with those given by oriental geographers. Longitude values, originally given with respect to the Meridian of Ferro and corrected in the table for that of Greenwich, also show better agreement with the modern values although there are remarkable discrepancies in the case of Ghazni, Srinagar, Lhasa. About Lhasa, the error is more than compensated for by his bold attempt to fix the geographical limits of Nepal about which information was then very scanty. Danet placed the province of Nepal between 25 and 30 degrees of latitude and between 101 and 105 degrees of longitude. Previously some information was available through the travel accounts of Fathers Grueber and Cysat (?) who travelled from China to India through Tibet and Nepal. Grueber fixed Lhasa's latitude at 29°6′.[42]

TABLE 2

Manucci's values of Latitudes and Longitudes as quoted by Tieffenthaler

Name of Place	Manucci						*'Āin*						Modern			
	Lat.		Long.				Lat.		Long.				Lat.		Long.	
			Fortunate Ils.		Greenwich				Fortunate Ils.		Greenwich					
	deg	min	deg	min	deg	min	deg	min	deg	min	deg	min	deg	min	deg	min
Kabul	36	20	113	50	78	20	34	30	104	40	69	10	34	18	69	11
Lahor	33		119	40	84	10	31	50	109	22	73	52	31	20	74	22
Multan	33	40	115	20	79	50	29	52	107	35	72	05	30	7	71	19
Delhi	31	45	123	0	87	30	28	15	114	38	79	08	28	23	77	07
Agra	29	20	123	0	87	30	26	43	115	0	79	30	27	06	78	30
Baker (or Mansura)	28	30	112	25	76	55	26	40	105	0	69	30	27	25	68	33
Ajmir	30	0	120	30	85	0	26	0	111	05	75	35	26	16	74	25
Benares	29	25	129	15	93	45	25	17	119	15	83	45	25	12	83	0
Ujjain	28		122	30	87	0	23	30*	110	50*	75	20	23	54	75	26
Patna	25	30	132	0	96	30	26	5	120	46	85	16	25	22	85	08
Rajmahal	24	20	132	0	96	30	—	—	—	—	—	—	25	02	87	32
Gujarat	23	0	116	30	81		23	15	108	30	73	0	23	0	73	18
Dacca	23	30	133	40	98	10	—	—	—	—	—	—	23	26	90	22
Golconda	19	40	124	40	89	10	18	4*	114	19*	78	49	17	14	78	16
Aurangabad	19	25	120	25	84	55	23	15	108	30	73	0	19	32	75	14

*From Astrolabe.

TABLE 3

Danet's values of Latitudes and Longitudes as quoted by Tieffenthaler

Name of Place	Danet						Modern			
	Lat.		Long.				Lat.		Long.	
			Meridian of Ferro		Greenwich					
	deg	min	deg	min	deg	min	deg	min	deg	min
Kashmir	35	0	87	30	70	15	34	36	74	30
Ladak (Latak)	34	50	97	30	80	15	32	0	80	—
Kabul	33	40	85	0	67	45	34	30	69	11
Kandahar	33	30	83	40	66	25	31	22	65	18
Ghazni	32	0	96	40	79	25	33	20	68	10
Lahor	32	0	91	30	74	15	31	20	74	22
Srinagar (Sirinagar)	31	30	96	20	79	05	34	36	74	30
Kumayun (Comaoum)	30	21	98	30	81	15	29	14	79	18
Multan	30	0	89	40	72	25	30	7	71	19
Lhasa (Lahassa) (Tibet)	28	30	113	50	96	35	29	24	91	30
Agra	27	15	94	40	77	25	27	6	78	30
Ajmir (Adjmeer)	25	40	92	0	74	45	26	16	'74	25
Chitor	23	30	92	30	75	15	24	32	74	25

TABLE 4

Father Boudier's values of Latitudes and Longitudes, as quoted by Tieffenthaler

Name of Place	Boudier						Modern			
	Lat.		Long.				Lat.		Long.	
			Paris		Greenwich					
	deg	min	deg	min	deg	min	deg	min	deg	min
Patna	25	38	83	15	86	0	25	22	85	8
Bankipur	25	33	83	24	86	9	25	24	85	7
Allahabad	25	26	79	35	82	20	25	17	81	32
Munghyr	25	20	84	31	87	16	25	14	86	18
Bhagalpur	25	18	84	59	87	46	25	9	87	1
Benares	25	12	80	47	83	35	25	12	83	0
Rajmahal	25	1	85	55	88	40	25	2	87	32
Murshidabad	24	11	86	41	89	26	24	7	88	12
Hoogly	22	56	86	2	88	47	22	33	88	16
Chinsura	22	54	86	3	88	48	22	32	88	16
Chandernagare	22	51	86	9	88	54	22	31	88	15
Calcutta	22	33	85	55	88	40	22	20	88	14

Elsewhere Tieffenthaler quotes Boudier's longitude value for Delhi as 94°54′, presumably from the longitude of Ferro. This value is reduced to 77°39′ with respect to Greenwich and compares favourably with the modern value of 77°7′.

Tieffenthaler, like D'Anville, made good use of Father Boudier's observations on latitudes and longitudes particularly in eastern India. Boudier was stationed with the French Jesuit mission at Chandernagore whose longitude he determined with good accuracy and also travelled up the Ganges, recording on the way the latitudes of Chinsura, Hooghly, Murshidabad, Rajmahal, Munghyr, Bhagalpur, Bankipur, Patna, Allahabad, Benares and other places. His values reproduced in Table 4, are taken from Tieffenthaler's *Geography*.[43] The accuracy of Boudier's values is clearly evident. The latitude values lie within a few minutes of modern values in most cases. The longitude values are consistently higher than modern values, lying between 26′ to 48′ in 7 cases, over 50′ in 2 cases and over 1° in 3 cases. We have transformed Boudier's values with respect to Greenwich by assuming the longitude of Paris as 2°45′, which is 33′ higher than the modern value. The excellence of Boudier's values in the mid-eighteenth century need hardly be overestimated.

TIEFFENTHALER'S OBSERVATIONS

Tieffenthaler's review of oriental and European geographers on the question of latitudes and longitudes is undoubtedly remarkable. He can also claim some merit in determining the latitudes of a large number of places and occasionally the longitudes of a few places. The material is scattered in his geography and mentioned in connection with his description of the provinces more or less on the pattern of the *'Āin*. Some of his results are summarized in Table 5.

A glance at the table would show that Tieffenthaler mostly determined the latitudes of places, more or less within the limits of observational accuracy in his days. In some instances he used an astrolabe for this purpose, as he clearly mentions while giving the value for Delhi as follows: 'La hauteur du pôle, que j'ai determinée au moyen d'un astrolabe, le 16 & le 17 Mai 1747, s'est trouvée de 28°25′.[44] Tieffenthaler's observations on the longitudes are few and far between. He has mentioned such determinations from observations of lunar eclipses, occultation of Jupiter and the transit of Mercury. From the lunar eclipse of April 26, 1744, he determined the longitude difference between Paris and Daman to be 4 hours 40 minutes equivalent to 70° (modern value 70°20′). He utilized the eclipse of March 7, 1746 to find the longitude difference between Agra and Bologna to be 4 hours 18 minutes, that is, 64°30′ (modern difference 67°17′). On February 2, 1744, Tieffenthaler measured from the occultation of Jupiter the longitude difference between Surat and Bologna to be 4 hours 2 minutes equivalent of 60°30′ (he wrongly converts it to 60°8′); the value compares well with the modern difference of 61°18′. These determinations and the trouble he took in making them from astronomical observations practically single-handed undoubtedly show his concern for the improvement of Indian geography.

In a number of places, Tieffenthaler mentions that he computed the longitude difference between two places from the route mileage. If the latitudes of two places and the distance between them are known, the longitude difference can be calculated

TABLE 5

Tieffenthaler's determination of Latitudes and Longitudes

Province	Place	Latitude	Longitude (from Ferro)	Remarks
Delhi & Agra	Delhi	28°25′	92°25′	obs. 6 & 7 May, 1747; long. inferior to Boudier's value.
	Agra	27°15′	93°14′ 95°23′	obs. 3 May, 1745; hardly any improvement.
	Narwar	25°30′	93°24′	obs. 1748.
Allahabad	Allahabad	25°9′	—	obs. 3 Feb., 1766.
	Benares	25°14′	80°51′	
	Jaunpur	25°38′	—	
	Gazipur	25°28′	—	
	Momohobba (near Calinjhar)	24°41′	—	obs. Feb., 1765.
	Calinjhar	24°42′	—	
	Rassein	24°49′	—	
	Thoroa	24°56′	—	obs. 3 March, 1765.
Oudh	Lucknow	26°34′	—	7 April, 1765.
	Gorakhpur	26°30′	—	11 March, 1770.
	Beraez	27°20′	—	—
	Khairabad	27°17′	—	—
	Balrampur	27°10′	—	4 March, 1770; calculated from route mileage.
	Pethana	28°50′	—	Calculated from route mileage.
	Nanamao	26°37′	—	12 November, 1769.
	Muhammadi	27°37′	—	11 April, 1769.
	Caercla	27°17′	—	6 December, 1769.
Ajmer	Ajmer	26°24′	92°45′	14 March, 1751.
	Sambhar	26°48′	93°8′	
	Jaipur	26°53′	93°43′	
	Sherpur	26°	—	
	Kotta	24°46′	—	
	Udaipur	25°	—	
	Lunavera	23°	—	
	Jalor	25°22′	—	1 March, 1751.
	Jodhpur	26°16′	—	6 March, 1751.
	Ujjain	23°12′	—	6 March, 1750.
	Sarangpur	23°30′	—	3 March, 1750.
Khandesh	Borhanpur	21°19′	—	From route mileage.
Gujarat	Ahmedabad	22°55′	—	21 January, 1751.
	Cambay	22°7′	—	14 January, 1751.
	Radhanpur	23°45′	—	February, 1751.
	Broach	21°30′	—	November, 1744; 10 January, 1751.
	Surat	21°5′	88°38′	2 February, 1744; longitude from occultation of Jupiter.
	Daman	20°6′	4h40′ or 70° from Paris	26 April, 1744; observed from lunar eclipse.
Bijapur	Goa	15°30′	4h9′ or 62°30′ from Bologna	
	Salsette	15°10′	—	In 1743; transit of Mercury.

by applying a formula due to Ptolemy. Ptolemy himself applied the formula to compute longitudes. Arab geographers, notably al-Bīrūnī used this method to compute longitudes in view of the fact that eclipses were rare phenomena and involved organizations[45]. But we do not find any indication of his applying this method in computing longitudes from route mileage.

These early efforts of the Jesuit missionaries gave place to organized surveys under the initiative of the Court of Directors of the East India Company from towards the end of the 18th Century and more particularly in the 19th Century. Between 1753 and 1788, the Company's Surveyors caused a mathematical survey to be made of a tract equal in extent to France and England taken together. Rev. William Smith, Thomas Deane Pearse, Ruben Burrow, Michael Topping and several others carried out large scale operations in longitude determinations by astronomical methods. Around 1800, William Lambton introduced the method of trigonometrical survey which led to the foundation of the Great Trigonometrical Survey of India. Lambton's work stimulated the study of geodesy in India; the geodetic arc was measured sector by sector along the vast stretch of land in one meridian; extensive pendulum operations were undertaken for finding the figure of the earth, which led to the discovery of gravity anomalies and the formulation of the theory of isostatic compensation. All these activities would have without doubt delighted the early eighteenth century pioneers like Joseph Tieffenthaler who were trying hard to find their bearings to develop Indian geography on solid foundations.

NOTES AND REFERENCES

[1] Bernoulli, Jean, *Description Historique et Geographique de l'Inde*, Vol I: La Geographie de l'Indoustan, écrite en Latin, sans le pays meme par le Pere Joseph Tieffenthaler, Jésuite & Missionnaire apostolique dans l'Inde. Berlin, 1786. This will be referred to as I.

[2] I, 9.

[3] I, 11.

[4] D'Anville in his *Êclaircissemens Geographiques sur la carte de l'Inde*, Paris, 1753, 101-102, discusses the values of latitude determinations by a number of observers and says that an English pilot gave the Cape a latitude of 7°50′, which was confirmed by a large map, in his possession, of the Malabar Coast. The same value was given by the Portuguese geographer Pimentel. Father Thomas observing from a high hill on which was located a Hindu temple determined its latitude at 8°5′, whereas Father Bouchet observing from the flat ground at the foot of the hill gave 7°58′, From these values D'Anville concludes that the latitude of Cape Comorin may be taken to be 8° plus a little more.

[5] I, 10. D'Anville gives Boudier's value as 86°5′ or 86°6′ reckoned from the Meridian of Paris (*Êclaircissemens*, 65). Referred to Greenwich which is 2°20′ west of Paris, Boudier's value reduces to 88°15′ or 88°26′ in close agreement with the modern value of 88°15′E. Tieffenthaler's figure places the meridian of Ferro at 17°28′ west of Greenwich as against the modern value of 17°W for Medeira Islands.

[6] *Eclaircissemens*, 65.

[7] Rennell, James, *Memoiry of a Map of Hindoostan*, 2nd Edition, 1791, p 38.

[8] I, 10.

[9] In Rennell's *Memoir*, the longitude of Tatta is given as 67°37′ (p. 179). The longitude of Chittagong calculated by adding 4°53′ to that of Balasore, 87°1′30″ (p. 9) is 91°54′30″, say 91°55′. The extension in longitude between Tatta and Chittagong works out to 24°18′. The longitude difference between Tatta (67°35′E) and Chittagong (92°32′E), as per modern values, is 24°57′.

[10] I, 10.

[11] I, 11.

[12] Phillimore R. H., *Historical Records of the Survey of India*, Vol I, Eighteenth Century, 1945, p. 153.

[13] *Ibid*, 318; quoted from British Museum Addl. Mss. 29233 (274).

[14] Rouben Burrow, before coming to India in 1783, was for sometime assistant to Maskelyne, Astronomer Royal and helped him in his observations of terrestrial attraction at Mt. Schehallien in Scotland. In India he was credited with some of the most important longitude determinations.

[15] I, 12.

[16] *'Ain*, III, 39-41. For *lambana* meaning longitude, see *Sūryasiddhānta*, V, 2; another word *deśāntara* is also used for longitude (*Sūrya-siddhānta*, I, 60). The significance of 180° is probably to indicate the limits of the habitable world. Al-Bīrunī says: "That the longitude of the inhabitable world is a half-circle is a far spread theory among their astronomers...." (*Alberuni's India*, 1, 304). *Yamakoṭī* (or *Āryabhaṭa's Yavakoṭi*) is the easternmost point, other places in the three other cardinal directions being Laṅkā, Romaka and Siddhapura;" Sunrise at Laṅkā is sunset at Siddhapura, midday at Yavakoṭī, and midnight at Romaka. (*The Āryabhaṭīya* of *Āryabhaṭa*. Eng. translation by Walter E. Clerk, 68, Chicago; 1930). See *Pañcasiddhāntikā*, XV, 23 (G. Thibaut, S. Dvivedi); *Sūrya-siddhānta*, XII, 38-41. For the method of determination of longitude, refer to *Sūrya-siddhānta*, I, 63-65 and the annotation of Burgess (Reprint of English translation, ed. P. Gangooly, with introduction by P. C. Sengupta, Calcutta, 1935, p. 47-48)). It may be noted that while the principle is basically the same, the Hindu astronomical texts give further rules for converting the longitudes obtained in time into distances in *yojanas* from their prime meridian. As to the prime meridian, the *'Ain* attributes it to the one passing through Yamakoti in the east as having 0° long. But in Hindu treatises, the meridian of Ujjain is taken to be the first meridian for such purposes. (See *Sūrya-siddhānta*, I. 62 and annotation of Burgess).

Al-Bīrunī writes: "The line on which the astronomical calculations are based (as 0° of longitude), which passes in a straight line from Laṅkā to Meru, passes—(1) Through the city of Ujain (Ujjayinī) in Mālvā. (2) Through the neighbourhood of the fortress Rohitaka in the district of Multan, which is now deserted. (3) Through Kurukshetra, i.e. the plain of Tāneshar (Sthānesvara), in the centre of their country. (4) Through the river Yamunā, on which the city of Mathura is situated. (5) Through the mountains of Himavant, which are covered with ever-lasting snow, and where the rivers of their country rise. Behind them lies Mount Meru". (*Alberuni's India*, I, 308).

[17] *'Āin*, 111, 32. *Ghari* is *ghaṭikā*, *nāḍī* or *nāḍikā*, a day being divided into 60 *ghaṭikās* (*Sūrya-siddhāntu*. 1, 11). It also gives the Hindu value of the degree as 14 *yojanas* plus a fraction (one-sixth of 84 yojanas and a fraction).

[18] The elevation of the pole or Tieffenthaler's 'la hauteur du pole' frequently employed is the *akṣonnati* of the Hindu astronomers (*Sūrya-siddhānta*, XII, 42). The equator has been defined to be a circle passing through places, inclusive of Laṅkā, at which the sun at the the equinoxes passes exactly overhead at midday and which have neither equinoctial shadow nor elevation of the pole (*akṣonnati*) (*lbld*). Āryabhaṭa's cryptic statement;—"The equinoctial sine is the sine of latitude. The sine of colatitude is its *koṭi*",—contains both definition and method. For details of finding latitudes when the sun is at either of the equinoxes or in general at any other time, vide *Sūrya-siddhānta*, III, 12-17.

[19] *Alberuni's India*, 1, 317.

[20] *Ibid*. Balabhadra composed a famous tantra and commented on Varāhamihira's *Bṛhajjātaka*. Vitteśvara (Vaṭeśvara) was the author of *Karaṇasāra*.

[21] *Memoirs*, 224, 186 (2nd ed.).

[22] I, 6.

[23]I, 13.
[24]I, 404. See also Jarret's note, '*Ain* 111, 33-44 (edit. 1894).
[25]*Êclaircissemens*, 49-50.
[26]*Memoirs*, 48, 63.
[27]*I*, 125.
[28]*Memoirs*, 66.
[29]*Éclaircissemens*, 65.
[30]I, 456; on p. 10, Tieffenthaler gives it as 105°53; there are several such discrepancies in reproducing figures.
[31]I, 13-14.
[32]I, 67, 75.
[33]I, 74.
[34]*Éclaircissemens*, 20.
[35]I, 102.
[36]I, 116.
[37]*Memoirs*, 93.
[38]I, 117.
[39]*Êclaircissemens*, 37.
[40]I, 121.
[41]I, 14, 15. Bernoulli noted that these values were taken from the French edition entitled *Histoire generàlsde I'Empire du Mongol depuis sa fondation. Iur les mèmoires portugais de M. Manouchi. Translated by Catrou, àla Haye*, 1708. English edition, trans. by W. Irvine, under the title *Storia do Mogor*, or *Mogol India*, 1653-1706, London, 1907-8.
[42]I, 16.
[43]II, 429.
[44]I, 125.
[45]Schoy, Carl, 'Aus der astronomischen Geographie der Araber', ISIS, **5**, 51-74, 1922. see also Sen, S.N., 'Al-Bīrūnī on the determination of latitudes and longitudes in India', *Indian Journal of History of Science*, **10**, 185-197, 1975.