11. *On the Curvature of Islands Arc.*

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A few years ago, the present author communicated before the Meeting of the Colloquium of our Institute a short note regarding a supposed relation between the radius of curvature, ρ, of islands arc and its latitude, φ, pointing out that there seems to exist a statistical tendency of a positive correlation between these two quantities.

The subject was recently resumed for a further investigation extending its scope a little more. The result will be briefly reported in the following.

The method of investigation is very simple. In the case of a large arc extending to several ten degrees, a globe of 19-inch diameter was taken and by means of a divider the approximate radius of curvature was estimated and the geographical coordinates, φ_0, λ_0, of its centre of curvature read off. For the shorter arcs Justus Perth's Maps were chiefly used. The latitude of the middle point of the arc, φ_m, was also noted down.

In some cases the arcs are very nearly circular but in many cases not so. In the latter cases there is a margin of arbitrariness in the choice of the circular arc which we assume as best conforming with the islands arc in question. Recently, Dr. Kumagai[1] of Kyoto Imperial University wrote an interesting paper on a method of determining the curvature of nearly circular arc, applying his method to the case of Japan Arc. As, however, the present paper deals with a very rough approximation for a large number of arcs, the simplest method above mentioned was preferred.

On the other hand, the narrow curved strip of land such as the part of Central America extending from Costa Rica to Panama was divided into two nearly circular segments and the respective curvatures were determined.

1) N. KUMAGAI, *Jap. J. Astr. Geophys.*, (1930), 1.

Mountain-ranges were also treated in the similar manner for comparison. In the case of a long extended range, the curvature varies continuously from a positive maximum to the next negative maximum, passing zero value between these two maxima. As, however, we take here the curvature as a measure of the degree of disturbance in the surface features of the earth, it will suffice that we take the maximum curvatures from among the continuously varying train of values, just in the same sense as we measure the intensity of a train of waves as the function of its maximum amplitudes.

In the case of Central-American Arcs the comparison with islands arcs may appear less objectionable than in the case of mountain-ranges. The discussions may, however, be at first suspended and we may proceed to a mere phenomenological comparison.

The results are tabulated in the following:

Table I.

Grp.	Arcs	Abbrev. in Fig.	Centre of Curv.		Centre of Arc.	Rad. of Curv.
			$\varphi_0°$	$\lambda_0°$	$\varphi_m°$	ρ km.
Pacific	Aleutian	Aleut.	62·0 N	179·2 E	51·7 N	1180
	Kurile	Kur.	57·7	127·4	47·0	1960
	Honsyû and Hokkaidô*	Hons.-Hok.	42·4	130·2	37·8	930
	Honsyû*	Hons.	41·0	131·5	35·9	800
	Loochoo	Looch.	31·8	121·3	26·3	860
	Marianna	Mar.	17·4	141·6	16·7	690
W. Indies	Cuba, western 3/4	Cub.	18·5	81·7 W	22·5	500
	Windward Is.	Wind.	14·2	64·2	14·0	360
	Costa Rica and W. half of Panama	Cost. Pan.	11·3	81·3	8·5	320
	Panama, eastern 2/3	Pan.	7·7	79·3	9·3	170
Atlantic	Cerigo, Kreta, Karpathos, Rhodos	Kr. Rh.	36·7	25·5 E	35·2	280
	Canaries Is.	Can.	30·0	15·8 W	28·0	240
	Cap Verde Is.	C. Verd.	16·4	24·6	15·3	180
Indian	Luzon, C. Bolinao-Palawan	Luz. Par.	13·8	114·0 E	11·7	660
	Camarines, Samar, E. Mindanao	Cam. Sam.	8·2	119·0	11·0	760
	Andaman, Nicobar	And. Nic.	11·0	100·0	10·5	830
	Sangi, Celebes	Sang. Cer.	3·5	122·5	11·0	340
	Halmahera, C. Bisoa-Tg. Libobo	Halm.	0·8	129·7	0·7	230
	Ceram, Selaroe	Cer. Sel.	5·9 S	129·3	4·5 S	170
	Java, Sumatra	Jav. Sum.	13·0 N	119·0	7·5	2400
	Seychelles, Mauritius	Sey. Maur.	12·9 S	52·7	12·9	1100

* For these two arcs, φ_0 and λ_0 are taken from Kumagai's paper cited.

Table II.

Grp.	Mountain-Ranges	Abbrev. in Fig.	Centre of Curv. φ_0°	Centre of Curv. λ_0°	Centre of Arc. φ_m°	Radius ρ km.
Asia	Stanowoi, northern arc.	Stan.	68 N	152 E	62 N	760
	Ural I, between polar circle and 60°N	Ur. I	61	75	63	850
	Ural II, between polar circle and 52°N	Ur. II	58	82	59	1280
	Tannu-ola	Tan.-ol.	49	94	51	280
	Sichota-alin	Sich.-al.	51	121	47	1250
	Altai	Altai	56	102	46	1250
	Altyn, Mus-tag-ata to Tokkus.	Altyn	42	81	36	400
	Alla-tag to Hindukush	Hind.	43	65	35	860
	Himalaya, Kashmir to Bhutan	Him.	39	89	29	1400
Europe and Mediterranean	Erg-Riesen Gebirge	Erz.-Ries	49	15	51	220
	Tatra to E. end of Karpath	Tatr.-Karp.	45	20	49	470
	Jura	Jur.	45	9	47	280
	E. parts of Karpath and Transsilv. Alps.	Karp.-Trans.	46	25	46	90
	Coltic Alps	Colt.	45	9	46	180
	Ligurian Alps	Lig.	43	9	45	140
	Sicily, Calabria	Sic. Cal.	39	14	38	180
	Lesser Atlas	L. Atl.	36	4 W	35	150
N. & S. Am.	S. Nevada to S. part of Cascade	Nev.-Casc.	43	110 W	40	1000
	Tolima to Misti	Tol. Mist.	4 S	15	7 S	1500
	Misti to Azufre	Mist. Azuf.	23	78	20	1000

These results are also plotted in the annexed figures, Fig. 1 and 2 taking the latitudes φ_m of the middle point of the arcs and the radii of curvature ρ for the abscissae and ordinates respectively. Another figure was also constructed taking the latitude φ_0 of the centre of curvature as abscissa. The qualitative character of the result is, however, not essentially modified by this substitution.

A rather remarkable fact will be observed at the first glance of Fig. 1, namely, the area of the figure may be divided into three regions by means of the two lines I and II such that in each of these regions are grouped those arcs which are situated in a certain coherent portion of the earth's surface. Firstly, the Pacific Group lies in the middle section intercepted between the lines I and II. Also the Group including the West Indies and Central America lies on the same section, though clustered nearer to the origin of coordinates than the Pacific Group.

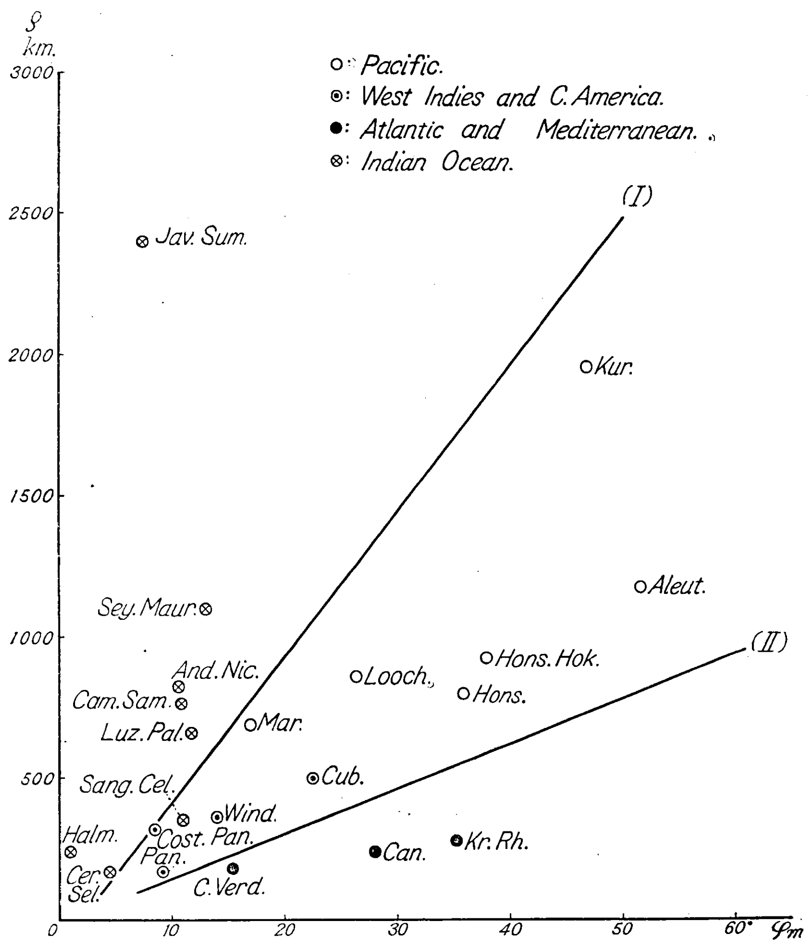

Fig. 1.

This is interesting, as the West Indies is usually cited as belonging to the Pacific type in morphological and petrological characters. Secondly, the Atlantic Group comprising Mediterranean arcs, lies entirely below the line II. Thirdly, the Indian Ocean Group comprising as far as Luzon is mostly above the line I.

Next, referring to the middle section containing the Pacific and the West Indies Groups, we may say that the radius of curvature increases

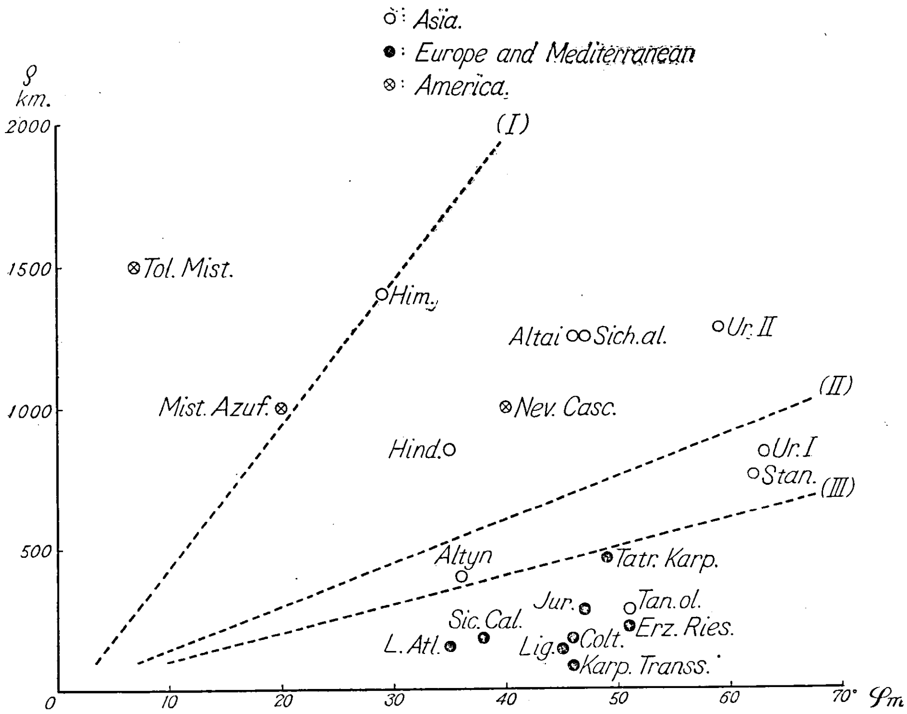

Fig. 2.

statistically with the latitude. The same may probably be said with respect to the other groups[2].

These facts seems to be too remarkable to be overlooked as merely accidental. The following suggestion may perhaps be proposed as plausible. The islands chains may be assumed to have been produced from less curved strips of sial mass by some non-uniform motion of the underlying sima mass. The space variation or fluctuation in the displacement due to this flow, of which the second space derivative is the

2) The irregularity in ρ-φ relation may in some measure be explained by taking the depth of the sea on the concave side of the arc into consideration, especially in the case of the Pacific Group. Thus, the relatively large values of ρ for the Kurile and Loochoo Arcs may be associated with the relative shallowness of the Okhotsk and China Seas respectively, compared with the Bering and Japan Seas. The exceptionally large ρ for Java-Sumatra arc allows the same explanation. An attempt was also made to find some correlation between ρ and the azimuth of the chord of the arc, but no apparent relation could be found.

On the other hand, it seems rather significant that the Marianna approaches the Indian Group and Sangi-Celebes instrudes upon Pacific Group.

essential factor for determining the average curvature, will generally increase with the average magnitude of the velocity of flow. Hence, the fact above noticed may signify that the general intensity of flow increases as we proceed from the pole to the equator. This is, however, just in harmony with what is believed to be the case from the arguments on other sides, if we consider that the thickness of the mobile sima layer increases towards the equator and that the increased thickness means the increased freedom of flow. This interpretation taken as provisionally granted, we may proceed a step further. Thus, for the *least disturbed*[3] Indian Ocean either the average velocity of sima flow might have been much less than for the most disturbed Atlantic Group, or the time elapsed since the beginning of the differential motion might have been less for the former than for the latter, since the curvature is determined by the total differential displacement, i.e. by the product of the differential velocity into the time.

Next, referring to Fig. 2 giving ρ-φ relation for mountain-ranges we will see that all of the European mountain-arcs fall in the same zone as the Atlantic and Mediterranean Groups of islands arcs, i.e. below the line II. Among the Asian mountains, Hindukush, Altai, Sichota-alin and a part of Ural fall in the Pacific Group, i.e. between I and II. Altyn, Stanowoi (northern arc) and another part of Ural lie on the boundary zone near the the line, II, while the arc of Tannu-ola alone falls amid the area occupied by the European mountains. Himalayan arc between Kashmir and Bhutan and also the South American arc between Misti and Azufre lie near the boundary line I. Another part of the South American arc between Tolima and Misti belongs to the Indian Ocean Group, while the N. American arc comprising Cascade and Sierra Nevada falls near Japanese Honsyû arc in the midst of the Pacific Group. The distribution may appear quite fortuitous, but if we consider the general statistical tendency we may notice a decided contrast between the European and Asian mountains. It is interesting to observe that in the case of mountain-ranges the line of demarcation between the Asian and European Groups may be drawn much lower than II, somewhere in the position as indicated by III in Fig. 2. S. and N. American taken as a whole may be said to be *less disturbed* than in the other part of the earth.

As to the geotectonic significance of mountain ranges there are

3) I.e. least curvature or largest ρ.

still many conflicting theories among the geologists and geophysists. In view of this important problem, the very fact that the ρ-φ relation throws many mountain-ranges into the same batch with the islands arcs in the respectively associated regions will be worthy of notice, as it may serve as a new item among the many pros and cons for and against the existing rival theories.

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11. 嶋弧の曲率に就て

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世界中の主なる嶋弧の概略の曲率半徑 ρ を求め、此れと共の弧の中心の緯度 φ_m との關係を圖示して見ると、(ρ, φ_m) 點の分布は全く無秩序ではなく、凡そ三つの群に分れ、それぞれの群は地球上での纒まつた區域に相當する。さうして統計的には各群に就き ρ が φ_m と共に増すやうに見える。又山脈弧に就ても同樣の結果が得られる。此結果から考へて、ρ は地殼表面の流動の局部異同によつて生じたものと想像され、もしさうだとすると、上記の ρ-φ_m 關係は、地球の部分により地殼移動の程度に差違あることを示すものと考へられる。
