

THE HYDROGRAPHY OF THE YUNNAN-TIBET FRONTIER

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ON the Yunnan-Tibet frontier, extending southwards along the frontier of Burma also, the supreme structural feature is the parallel arrangement and close proximity to one another of the great mountain chains separating the Tibetan-born rivers Yangtze, Mekong, and Salween. Issuing together from a narrow breach in the plateau-rim between the eastern end of the Himalaya uplift and the western end of the great watershed of China, these parallel ranges, however formed, have determined, at least in part, the upper courses of these rivers, as they now flow. It is of the minor structures raised on these massive foundations, not of the great ranges and rivers themselves, that I intend to write.

The drainage through what may be called the Sino-Tibetan gap flows southwards, parallel to the dividing ranges of granite, slate, schist, and limestone which, whether as actual prolongations of the Tibetan plateau or as independent uplifts (a question to be decided by future exploration), separate and enclose them. The rivers themselves from their birth set out eastwards, under the influence of the Central Asian east-and-west trending axes, but gradually they curve round through a right angle and flow southwards, breaching the rim of the Tibetan plateau as they change direction in conformity with the change in alignment of the mountain ranges.

On the flanks of the breach, through which the hurrying waters crowd southwards, the tendency is for the rivers to spread out fanwise and flow off east and west as the Yang-tze and the Brahmaputra, but the central rivers, hemmed in, continue southwards, crushed close together by the wall-like ranges.

These ranges, however uplifted, are features of original structure, as, indeed, so far as we are concerned here, are the river gorges between them. Later additions are the tributary valleys, with the peaks, passes, spurs, outliers, and similar minor features carved from them. The distinction is relative; simply, it is claimed that the parallel mountain chains, with their longitudinal rift-like valleys, fashioned in the long-distant past, have stood till now substantially as they were formed, during which time those details which make up the general scenery of the region, were engraved on them.

Since the main ranges trend from north to south, and the great rivers flow parallel to them, the tributary streams flowing down the flanks of the divides flow east and west.

Now the width of the divides is so inconsiderable, that although all the heavy rain comes from one direction—the south-west—yet that flank of the divide does not receive an appreciably heavier rainfall than does the other flank, though, on the other hand, the easternmost ranges, owing to their being screened from the impinging rain-clouds by the high ranges

further west, against which the moist winds first beat, do receive a progressively diminishing rainfall.

It is clear from this that no marked contrast is to be expected between streams flowing down one flank of a range and those flowing down the other, nor is any such difference found; further, that the westernmost range will be the most dissected by running water, the easternmost least; though, owing to the dense protective forests which, called to life by the adequate precipitation, clothe the former, contrasted with the nakedness of the latter, the resulting appearance is in each case considerably modified.

But with the spurs which, thrusting out east and west from the main divides, are thus blocked out, the case is different. These spurs present flanks to north and south in a region of heavy snowfall, and the contrast in the vegetation on the two slopes is apparent at a glance, and an index of conditions sufficiently different to have far-reaching consequences.

On north-facing slopes, trees (chiefly *Larix* and *Picea* sp.) extend to over 15,000 feet, and a thick tangle of scrub (*Rhododendron*, *Berberis Juniperis*) prevails to over 16,000 feet; while on south-facing slopes tree-growth ceases much lower down, and scrub-growth also somewhat lower. With the more scanty covering of vegetation on south-facing slopes occurs a marked accumulation of scree material. This contrast in the vegetation is a direct effect of the difference in aspect on north-facing and south-facing slopes. On the former, the lingering snow, protected from the spring sunshine, protects in turn the young plants and such seeds as are germinating, and, melting but gradually, ensures to them a constant supply of water.

On south-facing slopes the snow melts rapidly with the returning warmth, and is rudely stripped from the plant carpet at a critical moment, allowing the weakling plants to be exposed to rapid changes of temperature, involving considerable extremes; cold winds, too, play havoc with the delicate seedlings. In the second place this rapidly melting snow causes a volume of water to sweep down the mountain-side, doing great execution by direct attack. Here the poverty of vegetation reacts again. No soil can accumulate, since all the smaller rock *débris* is at once swept away by the water, which is consequently still less impeded in its abrupt descent, and the steepness of the slope depends on the angle at which the fallen material can rest. On the one flank, facing south, we have therefore steep rocky screes with a highly adapted flora of scree plants, poor in varieties; on the other, facing north, a gentler slope covered with a tangled carpet of dwarf shrubs, supporting a thin veneer of soil in which numerous plants can find foothold.

Into the question of plant-life under these abnormal conditions, however, I do not propose to enter here; it is sufficient for our purpose to note changes in the vegetation as indicating a change in the physical conditions, and to inquire first what change has taken place, and, secondly, what other changes does it involve.

If we look at a map of the Yunnan-Tibet frontier region, we notice a marked tendency amongst tributary streams to flow due south parallel to the main rivers, sometimes for a considerable distance, only turning east or west, as the case may be, to join abruptly the main river. The great divides having no thickness, it is evident that a stream simply flowing down from the crest-line for the very few miles which separate it from the next trough, would gather only a small volume of water to itself, as is in fact the case; but many of the tributary streams are of considerable size—are indeed rivers, and this volume they attain by flowing throughout most of their course parallel to the main river, collecting water over a large area. This fact is at once impressed on the traveller who voyages northwards along the frontier, as the smaller valleys, where existent, are utilized for the route in preference to the more difficult gorges of the main river. Moreover, the arid craggy troughs through which the Yang-tze, Mekong, and Salween have made their way offer scant opportunity for cultivation amongst their inhospitable cliffs and desiccated scree, most of the settled population being found away up on the flanks of the ranges.

These tributary streams have their birth, often in glaciers, far up under the peaks of the main watershed, and flow through comparatively open valleys, where are, in summer, broad meadows of gay flowers and mixed coniferous and deciduous-leaved trees; gradually the valley narrows, and tall cliffs grip the thundering water till, swinging abruptly round at right angles, the torrent grinds its way noisily through a jagged-walled arid gorge, and finally plunges into the main river.

This "reversed" valley, narrowing from a broad source in the mountains to a deep chasm at its confluence with the main valley, is characteristic of the region. It might seem, since the unusual—nay, unique—arrangement of the main divides has determined the parallel flow of the big rivers, that the tributary streams flow south for the same reason that they do; that is to say, that the tributary valleys are features of original structure. But every side valley shows clearly that it was carved out by running water, or, in its upper reaches, by ice, while there is nothing to show that the great troughs, though deepened by water, owe their existence to its action; indeed, such evidence as there is points to a tectonic origin. Moreover, the natural course of every tributary stream is down the flank of the main divide, and since some streams follow this course, while others show intermediate stages between this and the extreme south-flowing type, some other reason must be sought.

Consider first an ideal uplift (Fig. 1). Rain, falling equally on either flank of the divide, gives rise to streams which, cutting their way back at the head, block out peaks, separated by cols, thus producing an irregular crest-line. Spurs are formed buttressing the main watershed in the usual way. In the next stage, rain falling on the north and south flanks of these spurs starts a series of tributary streams, flowing north and south, as seen in Fig. 2.

Now, in consequence of that more rapid melting of the snow on south-facing slopes, evidence for which we have seen in the vegetation clothing them, streams flowing in this direction, coming down in spring spate, cut their way back at the head more rapidly than do those flowing idly and

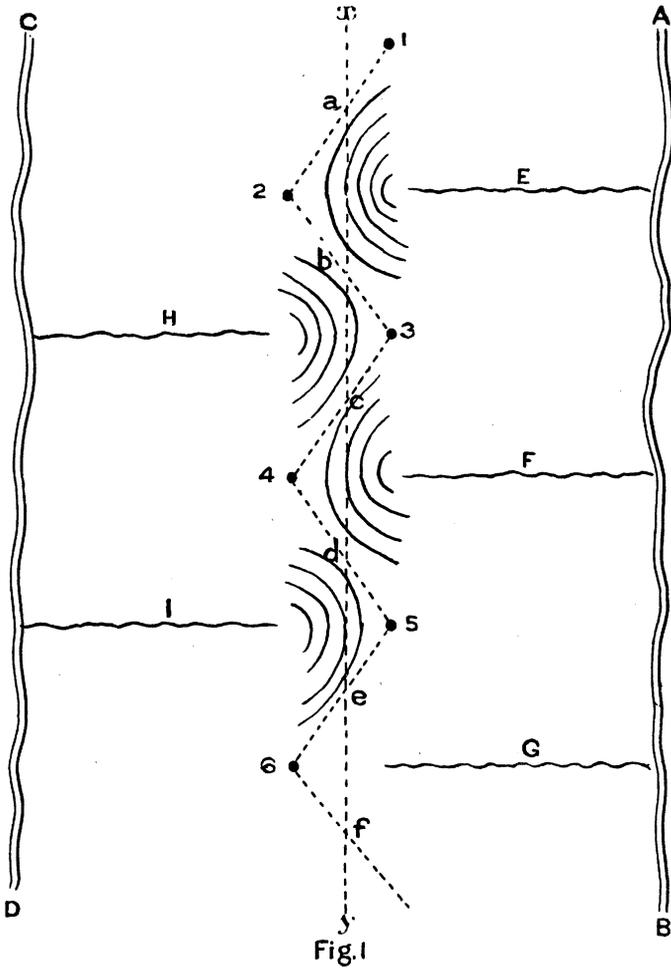
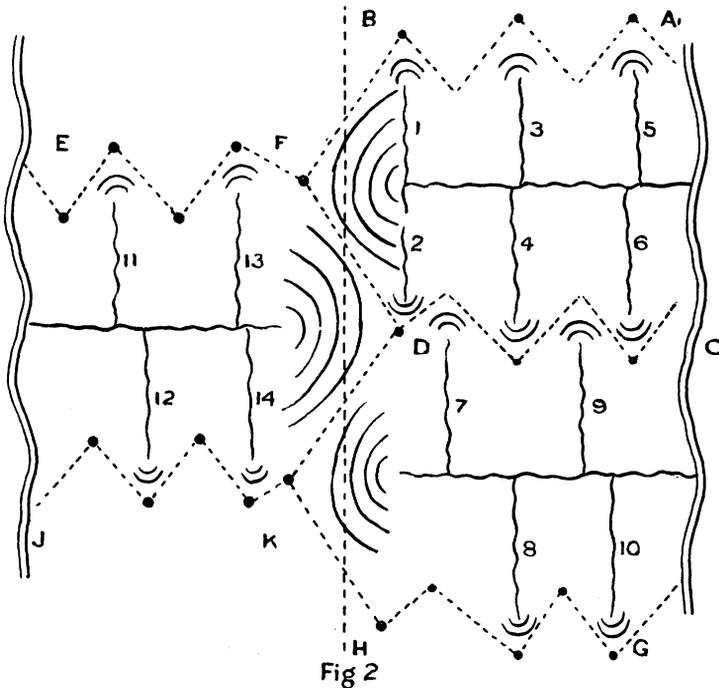


Fig. 1
The straight dotted line *xy* is the axis of original uplift; the zigzag line is the final watershed. AB, CD are main rivers; E, F, G, H, I tributary streams with cirques at their heads. 1, 2, 3, 4, 5, 6 are peaks on crest of main divide; a, b, c, d, e, f are cols between the peaks. The figure is drawn in recollection of a similar diagram in Professor Marr's 'Scientific Study of Scenery.'

with greater regularity—owing to the control exercised by the carpet of vegetation with its entangled soil-film—down north-facing slopes. The result is that, cutting thus rapidly back at the cirque, the south-flowing stream presently taps the headwaters of the next main tributary valley to

the north. Next, the increased water-supply enables the swelling stream to cut its channel deeper, while the beheaded stream in its lower course dwindles to a small current, or entirely disappears. At the same time the outline of a barrier range, flanking and parallel to the main range, is marked out. The cutting-back process proceeding, a second stream further north is beheaded, and gradually a spur running more or less diagonally from the middle flank of the range of the main river is carved out (Fig. 3).

Meanwhile the continual cutting back of all south-flowing streams at

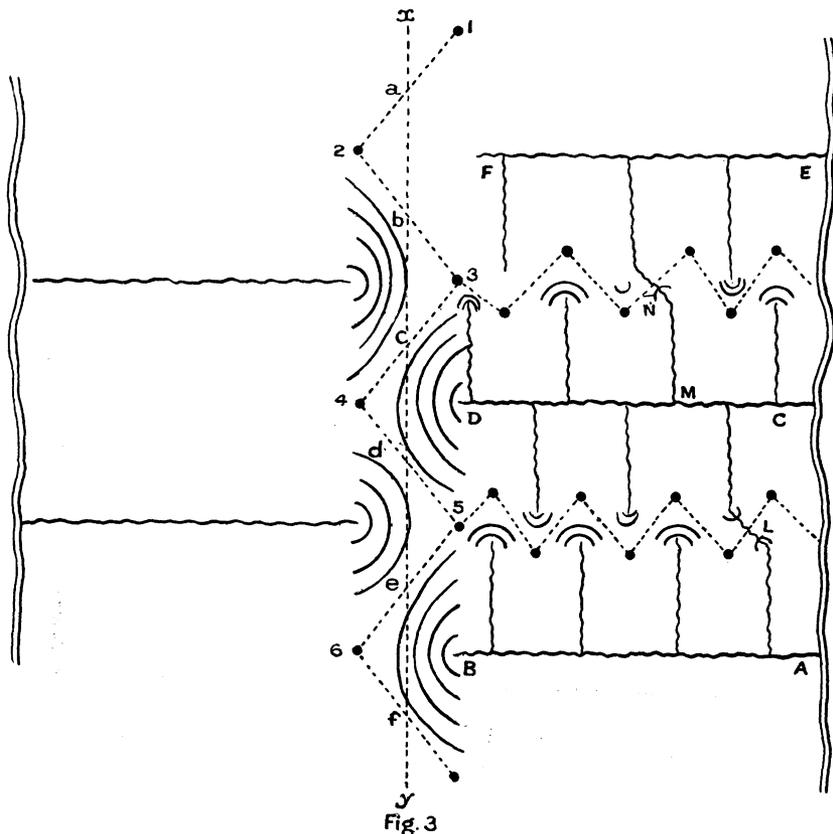


Peaks and cols as in Fig. 1. Nos. 1, 3, 5, 7, 9, 11, 13, are south-flowing streams from spurs AB, CD, EF; 2, 4, 6, 8, 10, 12, 14, north-flowing streams from spurs CD, GH, IK.

the cirques broadens the head of each valley, and with the capture of stream after stream, the original pirate stream, swollen with waters from every direction, still further scours its valley. (But some of the wide valley-heads are ice-worn.)

Lower down, however, especially along that part of its course which remains of the original east or west flowing stream, the waters are more confined as there is less lateral abrasion, the channel being already dug deep; at the same time the vastly increased load which the torrent now transports enables it to corrode its channel vertically with great rapidity.

The decrease in its powers of broadening the lower valley and concentration of effort at deepening it are due to two causes. In the first place, the extreme local aridity as the main trough is approached protects the walls of the gorge, which are attacked neither by rain nor by extreme variations of temperature. In the second place, throughout the frontier region the rocks, at least from the main troughs to an altitude of 12,000 or 15,000 feet, stand nearly vertical, and the strike runs about north-north-



Peaks and cols as in Fig. 1. The south-flowing stream AL of the main tributary AB has cut back through the spur at L, and tapped the next main tributary CD. MN has similarly tapped EF.

east to south-south-east, or even nearer the north and south line. Consequently, streams flowing in a north and south direction follow a course more or less along the strike of the rocks, while those flowing east and west cross the strike. In the case of schists and slates or shales, standing on edge, the former direction at right angles to the cleavage planes is the line of least resistance; as long as the stream follows the strike, the tendency is for it to cut a broad valley; when it cuts across the strike the tendency is for it to cut a narrow jagged-edged gorge. At high

altitudes also the effect of extreme temperatures and of rapid heating and cooling along the cleavage helps to widen the valley.

Indeed, even north-flowing streams may benefit from the advantage thus conferred by the strike of the rocks, and cut their way back sufficiently to tap a small stream to the south, as seems to have been the case with the stream flowing down to the Mekong from the Londre-la.

Eventually, owing to these changes, we find a long south-flowing and a short north-flowing branch of the main tributary. The barrier range to which these changes have given birth also sends small tributaries down either flank, on the one side to the main trough (recognizable by their size as not originating under the crest of the main divide, and often tumbling straight over the precipice, as in the "granite gorge" on the Salween above Cham-p'u-t'ong), on the other to the south-flowing stream. On the original lateral valleys, from which the headwaters have been stolen by the restless activity of these south-flowing streams, and on such valleys as are altogether ignored by them, absorbed in their greedy and headlong work, certain characteristic features are impressed.

Where a tributary stream from the main divide joins the south-flowing stream (which has crossed its valley and worked further north), there is often a waterfall, owing to the more rapid cutting down of its bed by what is now the main stream. The waterfall on what is now the main A-tun-tzw stream, coming down from the crest of the Mekong-Yangtze divide just below the village, seems to have been formed in this way. Originally the present source-stream probably flowed north through the shallow hanging valley above A-tun-tzw, to Adong. The south-flowing A-tun-tzw stream, cutting back at a lower level, tapped it and diverted it south over a fall, stranding the upper part of the Adong valley, where a lakelet has been formed by a barricade thrown across by a side stream.

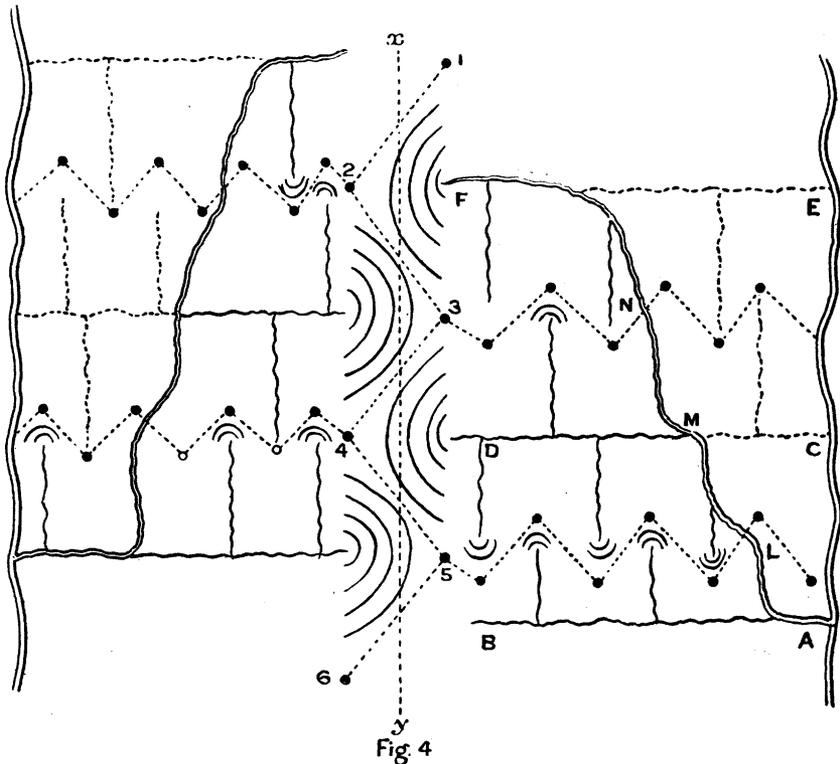
Again, many high-level valleys are left in the air owing to the turning of their water-supply and rapid deepening of the main channel. Other stranded or "hanging" valleys along this frontier were formed by the over-deepening of the main valley by water while the tributary valleys were filled with ice.

Hanging valleys—flat meadows with lakes or meandering streams—may also occur on the crest of the main divide, especially if a stream on one flank of the divide cuts back into a stranded valley on the opposite flank. The flat summit of the Londre-la (12,000–13,000 feet) on the Mekong-Salween divide is a hanging valley left in the air by the south-flowing stream running down to the Salween, and isolating Francis Garnier Peak (see Fig. 4). Similarly the south-flowing A-tun-tzw stream has isolated the massive outlier due west of the village, completely severing it from the Mekong-Yangtze divide.

Though it is scarcely profitable to point out detailed examples of the structures described, in a region so comparatively unfamiliar, still those acquainted with Major (now General) Davies' map of Yunnan will recog-

nize in the A-tun-tzw and Doker-la streams, and in those flowing from the Tsa-lei-la and Pai-ma-shan, most of the principles involved, as here set forth.

We have then an apparent confusion of ridges, valleys, peaks and outliers with waterfalls, valleys left hanging in mid-air, smoking screes and rushing torrents; then turning to the vegetation, we find meadows surrounded by flower-clad precipices occupying the broad alpine valley heads, magnificent mixed forests lower down, pine-clad slopes fronting



Lettering as in Fig. 3. Finally resulting south-flowing streams are shown by double line. The upper part of valley CD may be left in the air, owing to rapid cutting down of main stream; and there may be a fall at M. A barrier range is blocked out in the area AEF, streams flowing east and west from it.

the dry river gorges, stark screes with scattered plants, and in the deep valleys of the extreme west an approach to tropical jungle. On north and south facing slopes we find, as already pointed out, a marked difference both in the character and composition of the vegetation, and similar differences still more pronounced are met with as we pass from the easternmost range (the Mekong-Yangtze divide) to the westernmost (the Salween-Irrawaddy divide). Finally, we have to note that, owing to the isolation of barrier ranges by the activity of south-flowing streams,

their floras also are isolated more or less, with results well worth investigating.

While therefore, as described in a previous paper read before the Society, many of the hanging valleys and lake basins found at high altitudes on the Yunnan-Tibet frontier, owe their existence to a former generous extension of ice on all the main ranges, others are to be explained as a result of the unequal abrasion of north and south slopes; while also no explanation is offered of the main tributary valleys with broken backs (water or ice falls) nor of looped rivers (to be referred to presently), yet if the selective action of this principle as a sculpturing agent is fully realized: if the part played by a former unequal but universal extension of ice on the several ranges, is recognized, and the fact that these co-workers are in turn subordinate to a single control, namely, the prevailing south-west rain-bearing wind, owing to which the westernmost ranges tend to be washed away more rapidly than the arid easternmost ones, and consequently the westernmost rivers to be filched from their deep beds by yet deeper rivers and drawn headlong westwards—if these three sculpturing and denuding agencies are fully grasped and their several scopes defined—then I believe that the apparently inextricable tangle of spurs and tortuous river courses cease to present that overwhelming confusion which first greets the eye.

How far the argument cited above can be carried—whether by itself it is sufficient to account for the extraordinary courses met with in certain rivers of this region—is another matter. It is not difficult to see that, under certain conditions, a river might be forced to turn back on itself several times, and flow in a W-shaped course. But though the parallel loop does occur in several rivers along the Yunnan-Tibet frontier, and perhaps nowhere else in the world under similar conditions, still it is comparatively speaking so rare, and so striking an occurrence, that each individual case demands separate consideration; for doubtless the conditions are not precisely the same in each case, as for instance with the Ngawchang-hka on the rain-washed Burma side of the frontier, and the Wi-ch'u in the arid heart of south-east Tibet. Courses so whimsical in rivers as far asunder as the Ngawchang-hka, the Wi-ch'u, the Yangtze and the Yalung, which all display this feature more or less marked, cannot be explained by a formula.

In a paper published in the *Geological Magazine* ("Further Geological Notes from the Land of Deep Corrosions") in 1915, I stated that the folded and metamorphosed rocks found in all the river valleys led me to believe that, while the closely woven loops of such rivers as the Wi-ch'u and the Yangtze (at Likiang) resulted from the linking up of two originally distinct rivers flowing in opposite directions, such beheading of one stream by the other might be the result of earth-movement; in fact, movement in one direction combined with movement in another at right angles to the former, giving rise to a screwing motion. Such

movements may have actually taken place, giving rise to the east and west trending folds of the Himalayan ranges on the one hand, and to the north and south trending folds of the Yunnan-Tibet frontier on the other. But while there is good reason to believe that such rivers are in fact formed by the confluence of two originally separate streams, the junction may also be effected by the gradual and unequal cutting back of streams as described above, a process which can be seen, in all stages of accomplishment, now at work.

The Wi-ch'ü deserves a few words to itself. Like other main tributary streams of the frontier region, it flows due south throughout the greater part of its course and turns abruptly to join the Salween; but before reaching the confluence it indulges in the remarkable wriggle referred to, turning backwards and forwards on itself, loop lying against loop, where the river has impetuously torn its way out through the grandly savage mountain range as though lost in the wilderness and blindly seeking an exit. It is possible to stand on a ridge of rock, and looking down 1500 or 2000 feet, to see the river flowing due south on the one hand and due north on the other, so that it requires an effort of imagination to believe that it really is the same river. Such a wriggle would, of course, occasion no surprise in the case of a river meandering across a flood plain; but when it rushes through deep gorges, with stark rocky mountains capped by snow-peaks towering on every side, the effect is staggering. However, it would need a longer exploration of the valley than I devoted to it to say exactly what has happened, and I must leave it at that.

We may now draw attention once more to the influence this parallel arrangement of the main troughs and tributary valleys has on the people of the country, and on communication between valleys. Travelling up the main river gorges, along which lie the routes between Yunnan on the one hand and Ssuchuan and south-east Tibet on the other, very little cultivation is seen, and the population is correspondingly sparse; owing to the scarcity of rain, all fields need to be terraced and irrigated.

As already remarked, the tributary streams from the main ranges slit the valley walls with narrow jagged gorges, entrance to which is gained with difficulty. The roads from one main valley to the next, however, always follow the main torrents, that is, those flowing more or less south; similarly the roads up the big rivers often leave the main valleys and cross the spurs well up the flank of the divide, though there is generally an alternative track through the deep chasm where the big river rolls boisterously along.

Thus in Fig. 5 to cross from A to C it is necessary to follow the route ADC, while the route up the main valley AB lies parallel to but back from the main river, crossing the cols between the long south-flowing and short north-flowing streams, and turning back to the main trough through the narrow gorge where the joint stream breaks through. Thus crossing from valley to valley, the main peaks of the divide are

always outflanked, and though the route is made longer, the gradient is made easier than it would be in case of a frontal crossing of the main divide. The journey from Londre, on the Mekong, over the Doker-la to Aben on the Salween, is an instance of the first; that from the Mekong below A-tun-tzw, *viâ* that village and Adon, over the Tsa-lei-la and down to the Mekong again at Yá-ká-lo, an example of the second.

Once the difficulty of entering the tributary gorge has been surmounted, the valley begins to open out; cultivated slopes and villages are seen, and higher up broad alpine pastures. In fact, in the narrow Mekong basin at least, the population, hidden away behind the spurs and barrier ranges of the containing walls, considerably exceeds that of the main valley. It is

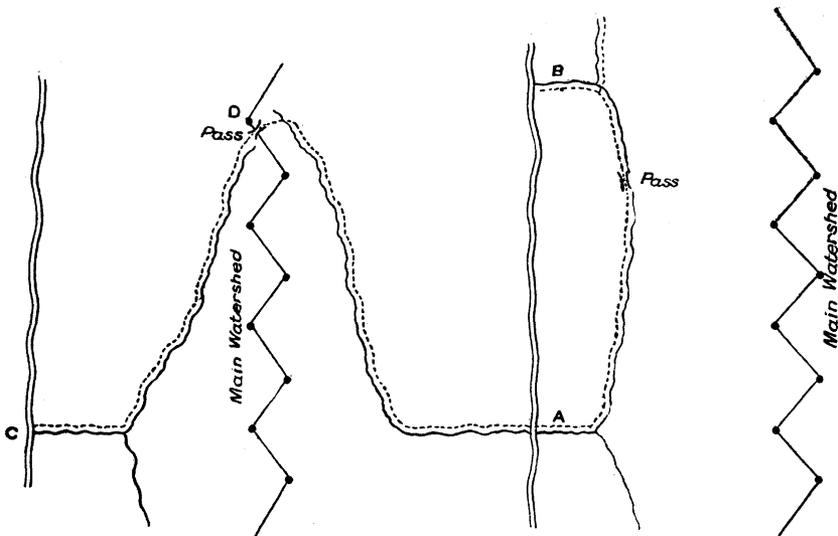


Fig 5

The route from A to C follows the south-flowing streams *viâ* D. Route from A to B follows the inland valleys higher up the flank of main divide, instead of keeping to main trough.

a new world which is opened up to the traveller behind these inhospitable and apparently impenetrable cliffs between 8000 and 12,000 feet high.

To what extent the facilities for intercommunication between the main troughs thus afforded have influenced the peoples of this region it is not easy to say. The routes from south-east Tibet into Yunnan, followed by large numbers of caravans each year, some of which come down as far as Burma, owe their existence to these valleys, and the recent westward movement of the Lisus from the Salween into the Burmese hinterland seems to be a direct result of this ability to cross apparently insuperable mountain barriers with comparative ease. Thus there is by no means that segregation of types one might expect to find in valleys so jealously isolated from one another, such differences as exist being dependent rather on climatic causes. For example, in the rainy region of

the Salween, which extends as far as 28° N., we find Lisus and (near the 28th parallel) Lutzw, giving place suddenly to a Tibetan tribe similar in appearance to the Mekong Tibetans, as soon as the arid region is reached, separated by a gorge, passable at certain seasons, and no more than a few miles in length.

Similarly, in the wetter southern portion of the Yunnan Mekong we find Chinese types, and in the arid northern part a Tibetan type; and there is a far wider difference between the tribes north and south of the Salween gorge just referred to than there is between the Tibetans of the Salween and those of the Mekong in the arid region, separated though these latter are by the vast bulk of the Mekong-Salween divide.

On the other hand, considerable as is the difference in appearance between the stone-built houses and irrigated terraces of the arid valley, and the timber houses and cultivated slopes of the higher flanks of the divide, there seems to be no difference between the valley and the alpine Tibetan of the Mekong basin.

There is one further point in the hydrography of this region, which must be briefly referred to, since it is perhaps the most important sculpturing agent, in its effects, at work on the region to-day. I mentioned at the beginning that the rainfall on either flank of any of the main divides was not appreciably different; at the same time, the westernmost ranges, acting as rain screens, receive a far heavier rainfall than do those lying further east. Consequently the snow-line on the Salween-Irrawaddy divide is much lower than it is on the Mekong-Yangtze divide, and this in turn brings other effects in its train.

But the chief point is, that the rain-bearing winds, beating up from the south-west, are impinging first on the Salween-Irrawaddy divide, and the tendency is for all watersheds to move eastwards, and hence for the water to flow, ultimately, not south, but west.

Thus the lesser principle, that tributary streams flowing east or west to a flank behead those lying to the north, one by one, is included in the greater, that the western main rivers will eventually behead and completely divert those further east.

A TRANSYLVANIAN BOUNDARY FOR RUMANIA: NOTES BY COLONEL R. ROSETTI (RUMANIAN ARMY) AND COLONEL SIR THOMAS HOLDICH

THE following notes have been communicated by the President for publication. The first is an extract from a letter written by a distinguished officer of the Rumanian Army, Colonel R. Rosetti, in criticism of certain passages in the recently published book: 'Boundaries in Europe and the Near East,' by Sir Thomas Holdich, reviewed in the *October Journal*. The second note is the author's reply.