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# Record of prolific and indubitable acritarchs from the Lower Paleozoic strata of the Tethyan Garhwal Himalaya and age implication

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Exceptionally well-preserved and prolific fossil acritarchs (a group of acid insoluble microfossils with uncertain affinities) have been recorded from the Shiala and Yong formations of the Tethyan Garhwal Himalaya, India. The presence of age marker forms of acritarch reveals that the Ordovician/Silurian boundary lies within the Shiala Formation and not at the contact of Shiala and the Yong formations, as was proposed by earlier workers<sup>1,2</sup>.

THE Lower Paleozoic acritarchs are known from throughout the world, especially from UK, USA, Canada, Norway, Spain, Belgium, Southern Africa, Russia, China and Arabian Sahara. However, the record from India is almost negligible due to rare occurrence of marine Paleozoic sediments in the Peninsular India. Only the simple *Leiosphaerids*, sphaeromorphs, acanthomorphs

and netromorphs, are so far recorded from the marine Precambrian/Cambrian rocks of the Peninsular India (Vindhyan, Kaladgi, etc.)<sup>3–6</sup> and the Extrapeninsular India (Krol belt, Lesser Himalaya, Tethys Himalaya)<sup>2,7–13</sup>. In the Extrapeninsular India, the Lower Paleozoic marine sediments are well recognized in the Tethyan zone of Kashmir, Spiti and Kumaon–Garhwal Himalaya and contain a variety of invertebrate Paleozoic fossils.

The term ‘Tethys’ was conceived by Suess<sup>14</sup> for a long expanse of Mesozoic seaway separating the old continental masses of the Gondwanaland in the south and Angaraland in the north. The ‘Tethys Himalaya’ refers to the widespread sedimentary basin to the north of the central crystalline rocks<sup>15,16</sup>. The Tethyan sediments range in age from Precambrian/Cambrian to Early Tertiary<sup>17</sup> and are rich in fossil contents. The Tethyan sediments of the Garhwal Himalaya have received

attention of geologists and palaeontologists since the initial work of Heim and Gansser<sup>18</sup>, but very little studies have been carried out on the palynological aspects so far, except that by Khanna *et al.*<sup>2</sup>. They reported the occurrence of chitinozoans, melanosclerites, *Baltisphaeridium* sp. and other microfossils from the Yong Limestone formation of the Tethyan Garhwal Himalaya. Earlier, Khanna<sup>19</sup> reported poorly preserved acritarch assemblage comprising nine genera assignable to 31 species from the Pin Dolomite sequence of Spiti valley, Himachal Pradesh.

The present acritarch assemblages (Figure 1) are recorded from the Shiala and Yong Limestone formations of Lower Paleozoic sediments exposed in and around the village Sumna (Lat. 30°40' and Long. 80°50'), which lies in the Chamoli district of Uttar Pradesh and close to the India-Tibet border (Figure 2). The altitude of area ranges approximately from 12,000 ft to 14,000 ft and the peaks are snow-covered throughout the year. The first author undertook two expeditions during August and September 1992 and 1993 to collect geological data and rock sample. The Sumna-Rimkhim mule track provides the excellent rock exposures and is the ideal section exposing a larger part of the Lower Paleozoic marine sequence. The exposed section comprises Garbyang, Shiala, Yong Limestone and Variegated formations.

Seventy-one rock samples at close intervals were systematically collected along Sumna-Rimkhim section (Figure 3). Strato-litho-petrographic column (Figure 4) has been prepared after careful computation and error correction of field observations<sup>20</sup> considering the aspects of topography, slope, traverse direction, altitude of exposed beds, lithology and petrographic characters. Thus, a total thickness of 680 m of the Lower Paleozoic marine sequence was systematically sampled along the section.

The integrated strato-litho-petrographic column shows age, name of formation (lithostratigraphic unit), thickness in meters, sample positions and names of rock types (Figure 4). Names of rock types, based on megascopic characters, have been given as limestone, sandstone, siltstone, siltyshale, etc. Subsequently, the precise and still more suitable names of rock types (lithounits), based on detailed petrographic study, have been given like mudstone (arenaceous), wackstone (bioclasts), boundstone (algal), grainstone (algal) and calcareous quartz arenite etc. as the classification of the sedimentary rocks<sup>21,22</sup>.

## Stratigraphy

A generalized lithostratigraphic framework of the Yong Gad section near Sumna has been given by Sinha<sup>23</sup> (Table 1), together with assemblage zones outlined by him.

All the 71 samples belonging to Garbyang, Shiala,

Yong and Variegated formations were subjected to standard maceration techniques for the recovery of acritarchs from its matrix. The heavy liquid analysis was done using KI, CdI<sub>2</sub> and ZnI. The samples of Shiala and Yong Limestone formations yielded prolific, varied and well preserved forms of fossil acritarchs belonging to subgroups sphaeromorphitae, acanthomorphitae, polygonomorphitae, herkomorphitae, diacromorphitae and netromorphitae. Rest of the samples from the Garbyang and Variegated formations have been found to be barren of acritarchs. The greenish grey, finely laminated silty-shale and the fine grained calcareous quartz arenite are the main lithounits which yielded fossil acritarchs from the Shiala Formation. Wackstone (bioclast) of the Yong Limestone Formation yielded abundant acritarchs which is greenish black.

This paper aims only to record the first prolific occurrence of acritarchs from the Indian subcontinent, in general, and from the Shiala and Yong Limestone formations of the Tethyan Garhwal Himalaya, in particular. All the slides and samples are deposited at the Department of Earth Sciences, University of Roorkee (India) for future reference.

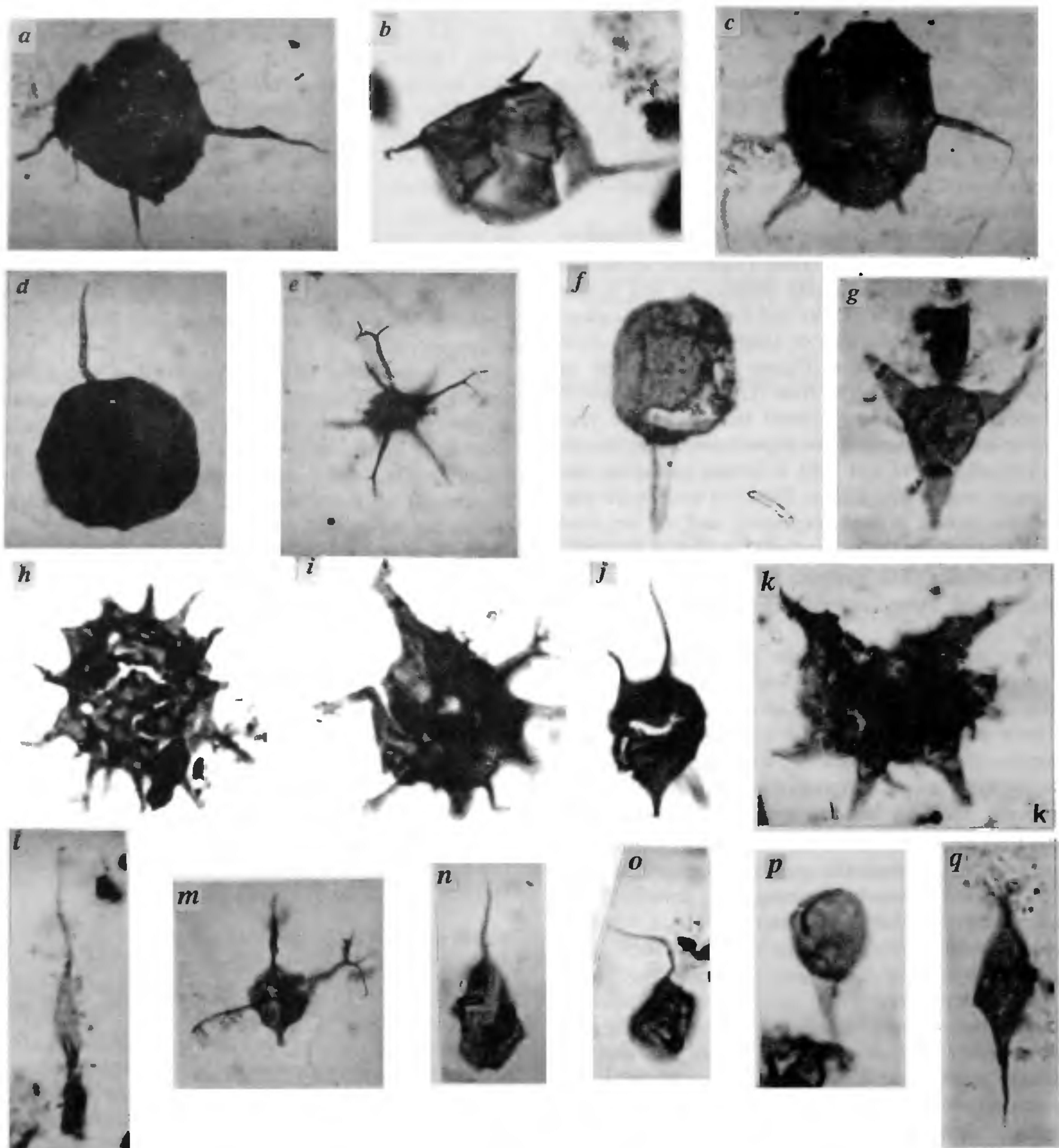
## Acritarch assemblages

The Tethyan acritarch assemblages are relatively smaller than the type species described<sup>24</sup>. According to our observation, the size may be extremely variable depending on the direction of folding during burial and preservational history<sup>25</sup>. A check-list of recovered acritarch species of Shiala and Yong Limestone formations is given in Table 2.

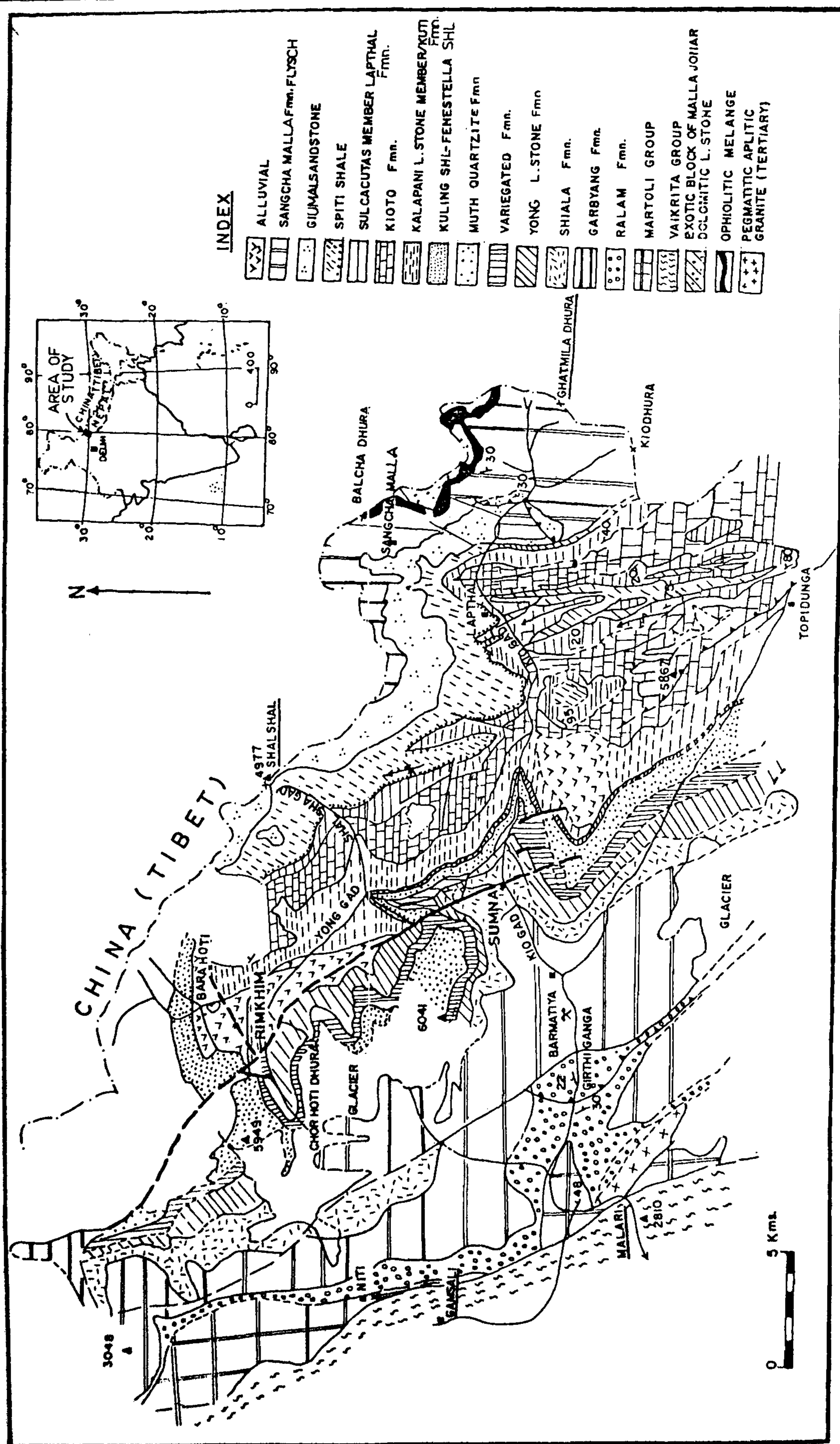
## Age implication

The acritarch assemblage recovered (Figure 1) from the Early Paleozoic sequence of Tethyan Garhwal Himalaya is mainly dominated by the acanthomorphs, polygonomorphs, netromorphs, herkomorphs and diacromorphs. The occurrence of age marker forms such as *Baltisphaeridium longispinosum* var. *longispinosum*, *B. archaicum*, *B. citrinum*, *Deunffia monacantha*, *D. brevispinosa*, *D. monospinosa*, *Geron* sp. cf. *G. amabilis*, *Triangulina* sp., *Domasia trispinosa*, *Multiplicisphaeridium cladum*, *M. thusui*, *Leiofusa parvitatis*, *L. algerensis*, *Veryhachium* sp. cf. *V. wenlockium*, *Stellichinatum celestum*, *Dactylofusa* sp. cf. *D. oblancae* and *Oppilatala? indiana* suggest Late Ordovician to Late Silurian age for the sediments exposed along the Sumna-Rimkhim section.

The sediments of the Shiala Formation yielded dominant to common occurrence of *Ordovician nudum*, *Multiplicisphaeridium ornatum*, *Veryhachium longispinosum*,



**Figure 1.** D = Maximum diameter of vesicle. *a*, *Baltisphaeridium archaicum*<sup>34</sup>; D = 30 µm, Slide No. R-8(2); Coord. 94.1 × 36. *b*, *Leiosphaera bernesiae*<sup>39</sup>; Longitudinal axis = 14 µm, Slide No. R-8(0); Coord. 104.3 × 70.6. *c*, *Baltisphaerosum bystrentos*<sup>36</sup>; D = 39 µm, Slide No. R-8(2); Coord. 95 × 31.3. *d*, *Deunffia monacantha*<sup>75</sup>; D = 24 µm, Slide No. R-8(2); Coord. 92.2 × 64.3. *e*, *Multiplicisphaeridium variable*<sup>41</sup>; D = 15 µm, Slide No. R-47(1); Coord. 94.6 × 60. *f* and *p*, *Geron* sp. cf. *G. amabilis*<sup>78</sup>; *f*, D = 6 µm, Slide No. R-8(0); Coord. 106 × 67.7, *p*, D = 8.5 µm, Slide No. R-8(0); Coord. 97 × 40. *g*, *Triangulina*<sup>61</sup> sp.; Largest process = 7 µm, Slide No. R-8(0); Coord. 103.3 × 40.1. *h*, *Multiplicisphaeridium cladum*<sup>28</sup>; D = 14 µm, Slide No. R-8(0); Coord. 104.6 × 52.3. *i*, *Multiplicisphaeridium thusui*<sup>47</sup>; D = 14 µm, Slide No. R-8(0); Coord. 104.1 × 63.4. *j*, *Domasia trispinosa*<sup>74</sup>; D = 10 µm, Slide No. R-8(0); Coord. 97 × 27.6. *k*, *Stellechinularum celestium*<sup>36</sup>; Length of body = 12 µm, Slide No. R-21(5); Coord. 111 × 33.7. *l-q*, *Leiosphaera parvitatis*<sup>40</sup>; *l*, length of vesicle = 7 µm, Slide No. R-47(0); Coord. 94.8 × 47.8. *q*, length of vesicle = 10 µm, Slide No. R-8(0); Coord. 106.7 × 32.7. *m*, *Oppilatata? indianae*<sup>49</sup>; D = 24 µm, Slide No. R-47(2); Coord. 94 × 30.9. *n, o*, *Deunffia monospinosa*<sup>74</sup>; *n*, D = 8 µm, Sample No. R-8(0); Coord. 102.6 × 69.4. *o*, D = 6 µm, Sample No. R-8(0); Coord. 99.9 × 63.9.

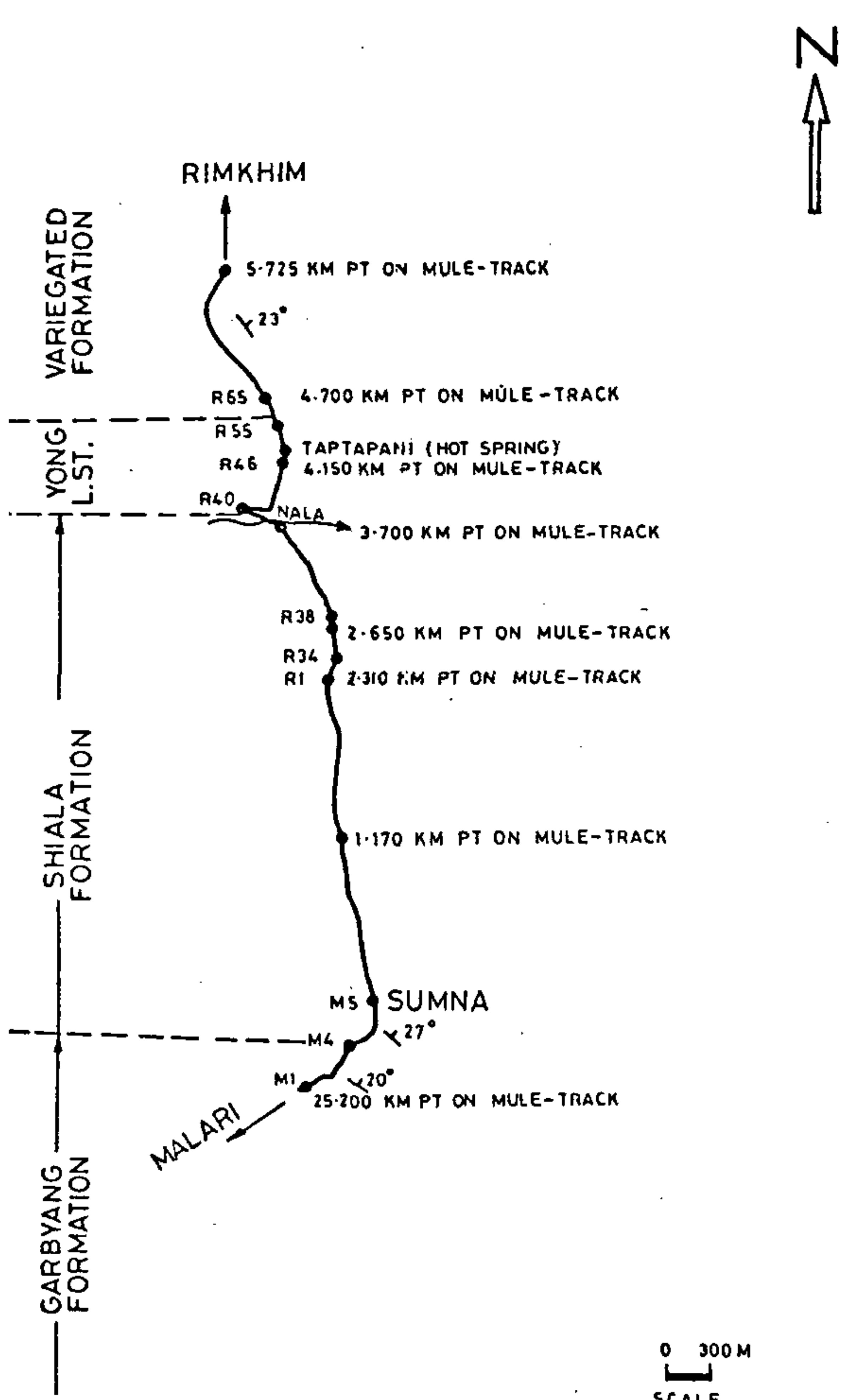


**Figure 2.** Geological map of the Malsari-Laphthal area of the higher Garhwal Himalaya, India (A. K. Sinha 1985)

*Filisphaeridium henryi*, *Neovervhachium* sp., subdominant presence of *Micrhystridium robustum*, *M. parinconspicuum*, *Acanthodiacrodium simplex*, *Solisphaeridium nanum*, *Baltisphaeridium citrinum* and *Coryphidium miladum* along with restricted occurrence of *Baltisphaeridium longispinosum* sub sp. *delicatum*, *B. archaicum*, *B. longispinosum* var. *longispinosum*, *B. bystrentos*, *Deunffia monacantha*, *D. monospinosa*, *D. brevispinosa*, *Domasia trispinosa*, *D. algerensis*, *Geron* sp. cf. *G. amabilis*, *Leiofusa parvitatis*, *Multiplicisphaeridium cladum*, *M. thusui* forms which are globally restricted to Caradocian to Wenlockian age<sup>28,30,33,36,37,40,44,62,75,76,80-91</sup>.

Therefore, Caradocian to Wenlockian age is assigned to the Shiala Formation.

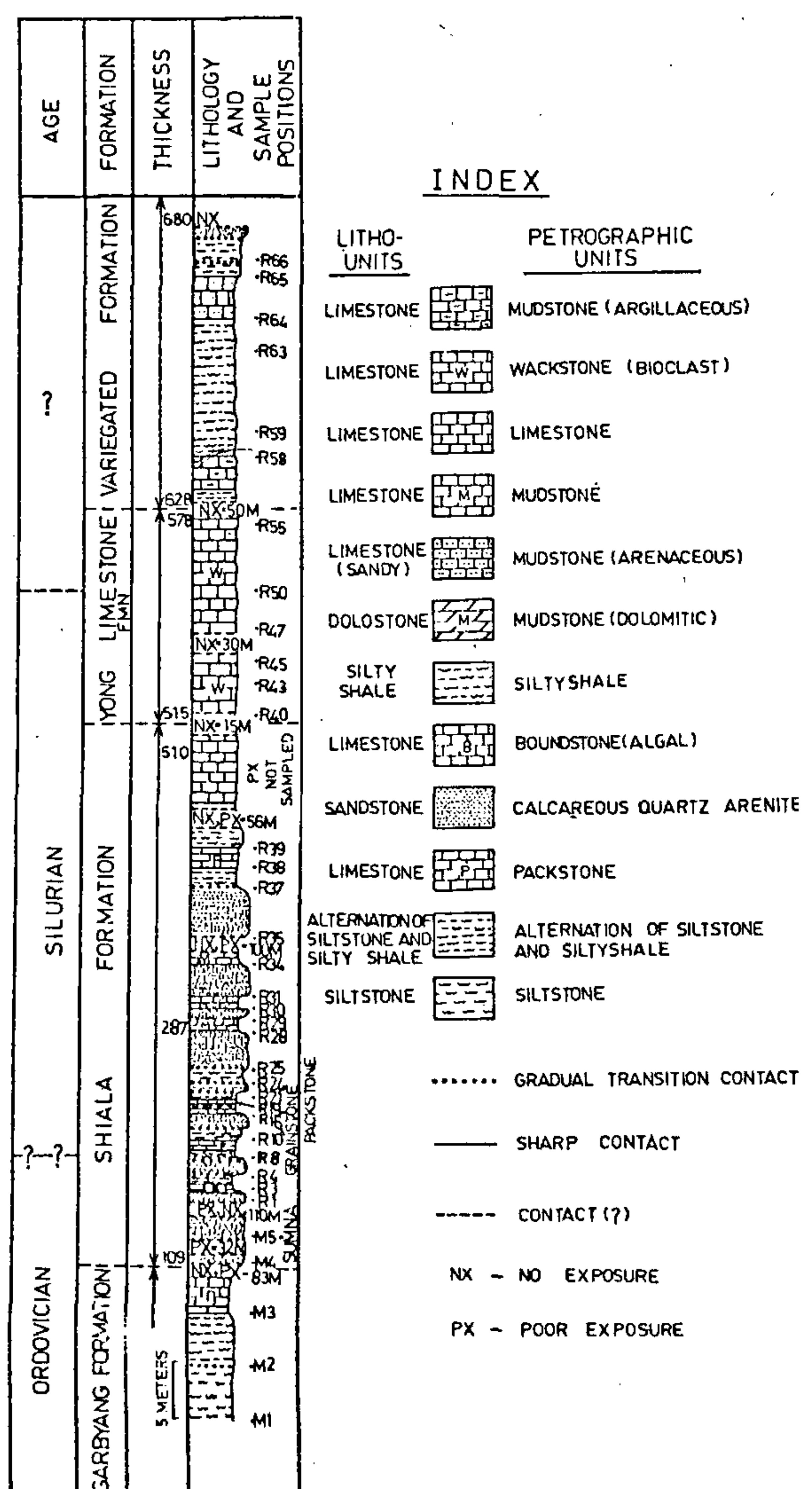
The Yong Limestone Formation yielded marker acritarch species, such as, *Leiofusa bernesiae*, *Oppilatala?*



**Figure 3.** Sumna-Rimkhim mule-track section showing location of samples.

*indianae* and *Multiplicisphaeridium variable* which have been described from Ludlovian sediments of various places<sup>28,34,45,80,92,93</sup>. Therefore, Late Silurian age (Ludlovian) is inferred for the Yong Limestone Formation.

The sediments overlying the Yong Limestone Formation belong to the Variegated Formation and are observed to be devoid of acritarchs. However, the Muth Quartzite section which overlies the Variegated Formation has yielded rich assemblages of brachiopod (*Pentamerifera* sp.) of the Late Silurian age<sup>94</sup>. The record of Late Silurian brachiopod in the top horizon of the Muth quartzite sequence suggests Ludlovian age for the Variegated Formation.



**Figure 4.** Integrated strato-litho-petrographic column of Sumna-Rimkhim section along the right bank of Yong Gad Valley showing sample positions.

**Table 1.** Generalized lithostratigraphic framework (Sinha, 1989)

Time unit	Lithounit	Broad lithology	Assemblage zones
Silurian	Variegated Formation	Purple l.st and shl. with bands of quartzite	<i>Strophonella</i> zone
	Yong Limestone	Green nodular biohermal and biostromal l.st.	<i>Calostylis</i> zone
Ordovician	Shiala Formation	Grey to pinkish s.st. quartizite, l.st.	<i>Rafinesquina</i> alternate zone
		Alternate bands of s.st. and shl.	<i>Monotrypa</i> zone
	Garbyang Formation	Alternate bands of greenish shl. and biostromal l.st., splintery shl. with arenite	<i>Rafinesquina aranea</i> zone, <i>Orthis testudinaria</i> zone
		Green needle shl. with occasional limestone	

**Table 2.** Check-list of recovered acritarch species from Shiala and Yong Limestone formations

Group	: <b>Acritarcha</b> <sup>26</sup>	
Subgroup	: <b>Sphaeromorphitae</b> <sup>27</sup> , <i>Lophosphaeridium</i> <sup>28</sup> , <i>L. parvum</i> <sup>27</sup> ; Sample No. R-21, <i>Lophosphaeridium</i> sp.; Sample No. R-12	5. <i>Neovervhachium</i> <sup>38</sup> , <i>Neovervhachium</i> sp. A 6. <i>Orthosphaeridium</i> <sup>58</sup> , aff. <i>Orthosphaeridium</i> sp.; Sample No. R-50 7. <i>Polygonium</i> <sup>38</sup> , <i>P. delicatum</i> <sup>39</sup> , <i>P. gracile</i> <sup>59</sup> ; Sample No. R-8, 12, 47, <i>Polygonium</i> sp. A., Sample No. R-43 8. <i>Stellechinatum</i> <sup>36</sup> , <i>S. celestum</i> <sup>36</sup> , <i>Stellechinatum</i> sp. A; Sample No. R-21
Subgroup	: <b>Acanthomorphitae</b> <sup>27</sup>	9. <i>Tetradinium</i> <sup>60</sup> , <i>Tetradinium</i> sp. A.; Sample No. R-21, R-47 10. <i>Triangulina</i> <sup>61</sup> , <i>Triangulina</i> sp. A 11. <i>Veryhachium</i> <sup>38</sup> , <i>V. calandrae</i> <sup>62</sup> , <i>V. downiei</i> <sup>63</sup> , <i>V. lairdii</i> <sup>64</sup> ; Sample No. R-21. <i>V. longispinosum</i> <sup>65</sup> , <i>V. oklahomense</i> <sup>40</sup> , <i>V. reductum</i> <sup>66</sup> , <i>V. valiente</i> <sup>61</sup> , <i>V. sp. cf. V. wenlockium</i> <sup>66</sup> , <i>Veryhachium</i> sp. A 12. <i>Villosacapsula</i> <sup>67</sup> , <i>V. sp. cf. V. entrichos</i> <sup>38</sup> , <i>Villosacapsula</i> sp.
	1. <i>Aremoricanium</i> <sup>30</sup> 2. <i>A. sp. cf. A. simplex</i> <sup>31</sup> , <i>Baltisphaeridium</i> <sup>32</sup> , <i>B. accinctum</i> <sup>33</sup> , <i>B. archaicum</i> <sup>34</sup> , <i>B. citrinum</i> <sup>35</sup> ; Sample No. R-21, <i>B. longispinosum</i> sub sp. <i>delicatum</i> <sup>36</sup> , Sample No. R-5, <i>B. longispinosum</i> var. <i>longispinosum</i> <sup>37</sup> ; Sample No. R-5, <i>Baltisphaeridium</i> sp. A 3. <i>Baltisphaerosum</i> <sup>36</sup> , <i>B. bystrentos</i> <sup>36</sup> 4. <i>Buedingiisphaeridium</i> <sup>38</sup> , <i>B. tremadocum</i> <sup>39</sup> 5. <i>Cheleutochroa</i> <sup>36</sup> , <i>C. diaphorosa</i> <sup>36</sup> 6. <i>Diexallophasis</i> <sup>40</sup> , cf. <i>Diexallophasis</i> sp., Sample No. R-47 7. <i>Filisphaeridium</i> <sup>38</sup> , <i>F. henryi</i> <sup>38</sup> 8. <i>Helosphaeridium</i> <sup>28</sup> , <i>H. citrinipeltatum</i> <sup>41</sup> ; Sample No. R-21, <i>H. sp. cf. H. clavispinulosum</i> <sup>28</sup> 9. <i>Micrhystridium</i> <sup>38</sup> , <i>M. ? diornamentum</i> <sup>39</sup> , <i>M. equispinosum</i> <sup>36</sup> , <i>M. exiguum</i> <sup>39</sup> , <i>M. parinconspicuum</i> <sup>42</sup> , <i>M. robustum</i> <sup>43</sup> , <i>M. shinetonense</i> <sup>43</sup> , <i>M. sp. cf. M. shinetonense</i> <sup>44</sup> , <i>Micrhystridium</i> sp. A 10. <i>Multiplicisphaeridium</i> <sup>44</sup> , <i>M. cladum</i> <sup>28</sup> , <i>M. ornatum</i> <sup>45</sup> ; Sample No. R-3, <i>M. osgodense</i> <sup>46</sup> , Sample No. R-47, <i>M. thusut</i> <sup>47</sup> , <i>M. variabile</i> <sup>41</sup> , <i>Multiplicisphaeridium</i> sp. A 11. <i>Oppilatala</i> <sup>48</sup> , <i>O? indiana</i> <sup>49</sup> ; Sample No. R-47 12. <i>Ordovicidium</i> <sup>50</sup> , <i>O. nudum</i> <sup>33</sup> ; Sample No. R-11, R-17 13. <i>Peteinosphaeridium</i> <sup>51</sup> , <i>Peteinosphaeridium</i> sp. 14. <i>Solisphaeridium</i> <sup>52</sup> , <i>S. nanum</i> <sup>36</sup> ; Sample No. R-21, <i>Solisphaeridium</i> sp. A 15. <i>Vulcanisphaera</i> <sup>53</sup> , <i>V. imparilis</i> <sup>53</sup> ; Sample No. R-11 16. <i>Stelliferidium</i> <sup>54</sup> , <i>S. redonense</i> <sup>54</sup>	Subgroup : <b>Herkomorphitae</b> <sup>27</sup> 1. <i>Cymatirosphaera</i> <sup>68</sup> , <i>C. sp. cf. C. celtica</i> <sup>69</sup> , <i>Cymatirosphaera</i> sp. A 2. <i>Cymatiogalea</i> <sup>54</sup> , <i>Cymatiogalea</i> sp. A; Sample No. R-21
Subgroup	: <b>Polygonomorphitae</b> <sup>27</sup>	Subgroup : <b>Diacromorphitae</b> <sup>27</sup> 1. <i>Acanthodiacyodium</i> <sup>70</sup> , <i>A. rotundatum</i> <sup>71</sup> , <i>A. simplex</i> <sup>72</sup> 2. <i>Dasydiacyodium</i> <sup>73</sup> , <i>Dasydiacyodium</i> sp. A.; Sample No. R-47. <i>D. sp. cf. D. longicornutum</i> <sup>71</sup>
	1. <i>Coryphidium</i> <sup>55</sup> , <i>C. miladum</i> <sup>56</sup> ; Sample No. R-17, R-12 2. <i>Dorsennidium</i> <sup>38</sup> , <i>D. rhomboidium</i> <sup>38</sup> , <i>D. minutum</i> <sup>38</sup> , <i>D. europaeum</i> <sup>38</sup> , <i>Dorsennidium</i> sp. A 3. <i>Goniosphaeridium</i> <sup>51</sup> , <i>G. splendens</i> <sup>36</sup> ; Sample No. R-21 4. <i>Impluviculus</i> <sup>57</sup> , <i>I. sp. cf. I. stellum</i> <sup>39</sup>	Subgroup : <b>Netromorphitae</b> <sup>27</sup> 1. <i>Dactylofusa</i> <sup>62</sup> , <i>D. sp. cf. D. oblancae</i> <sup>62</sup> ; Sample No. R-47. 2. <i>Deunffia</i> <sup>62</sup> , <i>D. brevispinosa</i> <sup>74</sup> , <i>D. monacantha</i> <sup>75</sup> , <i>D. monospinosa</i> <sup>74</sup> 3. <i>Domasia</i> <sup>76</sup> , <i>D. algerensis</i> <sup>76</sup> , <i>D. limaciforme</i> <sup>62</sup> ; Sample No. R-39, <i>D. trispinosa</i> <sup>74</sup> , <i>Domasia</i> sp. A.; Sample No. R-47 4. <i>Eupoikilofusa</i> <sup>62</sup> , <i>Eupoikilofusa</i> sp. A 5. <i>Geron</i> <sup>77</sup> , <i>G. sp. cf. G. amabilis</i> <sup>78</sup> , <i>Geron</i> sp. A 6. <i>Leiofusa</i> <sup>62</sup> , <i>L. algerensis</i> <sup>62</sup> , <i>L. bernesgae</i> <sup>79</sup> , <i>L. elenae</i> <sup>79</sup> ; Sample No. R-15. <i>L. parvitalis</i> <sup>40</sup> ; Sample No. R-47, <i>Leiofusa</i> sp. A.

All the genera/species are extracted from sample No. R-8-siltyshale, unless mentioned otherwise.

## Discussion

The acritarch studies of the Sumna-Rimkhim section of the Tethyan Garhwal Himalaya have provided fresh impetus to the stratigraphy of this region and revised the earlier date assigned to the Shiala Formation.

The earlier work<sup>223</sup> suggests that the Ordovician-Silurian boundary lies within the lower part of the Yong Limestone Formation. However, the recognition of stratigraphically important acritarch species suggests that the Ordovician-Silurian boundary lies within the Shiala Formation at 2.320 km pt on the Sumna-Rimkhim mule track section (Figure 3) and at the sample position [No. R-8 (Figure 4)]. This shows that the lithostratigraphic boundary may not coincide with the biostratigraphic boundary.

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