GEOLOGICAL REPORT ON THE RECONNAISSANCE SURVEY (G-4 STAGE) FOR POLYMETALS
IN
AMRITPUR AREA
DISTRICT: NAINITAL, STATE: UTTARAKHAND
(Under NMEDT Programme)

(TEXT, ANNEXURES AND PLATES)

A MINI RATNA COMPANY

MINERAL EXPLORATION AND CONSULTANCY LIMITED

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CORPORATE OFFICE, NAGPUR

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अमृतपुर क्षेत्र, नैनीताल में पॉलीमेटल्स के लिए गवेषण सर्वेक्षण (G-4 चरण) पर भूवैज्ञानिक रिपोर्ट

अध्याय –I

कार्यकारी सारांश

1.1.0 परिचय

1.1.1 अमृतपुर ब्लॉक उत्तराखंड के नैनीताल जिले में विवर्तनिक (टेक्टोनिक) रूप से सक्रिय लेसर हिमालयी क्षेत्र में स्थित है और लगभग 25.77 वर्ग किलोमीटर के क्षेत्र में फैला हुआ है, जो भारतीय सर्वेक्षण (सर्वे ऑफ़ इंडिया) के टोपोशीट संख्या 53O/11 के अंतर्गत आता है। इस ब्लॉक को G-4 स्तर आवीक्षण (रिकोनसिएन्स) के गवेषण के लिए चुना गया है, ताकि तांबा (Cu), सीसा (Pb), जस्ता (Zn) और उनके साथ जुड़े चांदी (Ag) एवं सोने (Au) के पॉलिमेटालिक खनिजीकरण की क्षमता का मूल्यांकन किया जा सके। भूवैज्ञानिक रूप से, इस क्षेत्र में ज्वालामुखीय, अवसादीय और ग्रेनाइटिक चट्टानों का एक विषम संयोजन शामिल है, जिसमें रायोडैसिटिक ज्वालामुखी, लौहयुक्त क्वार्टज़ाइट, परिवर्तित मैफिक चट्टानें और ग्रेनाइटिक बॉडी शामिल हैं, जो संरचनात्मक रूप से क्षेत्रीय विवर्तनिक तत्वों जैसे मेन बाउंड्री थ्रस्ट (एमबीटी) और संबंधित अपरूपण क्षेत्रों से प्रभावित हैं।ये लिथोलॉजिकल और संरचनात्मक स्थितियाँ हाइड्रोथर्मल द्रव परिसंचरण और खनिजों के निक्षेपण के लिए अनुकूल परिस्थितियाँ प्रदान करती हैं।

1.1.2 तांबा, सीसा और जस्ता जैसी आधार धातुएँ (बेस मेटल) बिजली और इलेक्ट्रॉनिक्स, निर्माण, परिवहन, अक्षय ऊर्जा प्रौद्योगिकियों और मिश्र धातु निर्माण सहित विभिन्न क्षेत्रों के लिए आवश्यक कच्चा माल हैं। जबकि, चांदी और सोने जैसी बहुमूल्य धातुएँ इलेक्ट्रॉनिक्स, आभूषण, निवेश और उभरते तकनीकी अनुप्रयोगों में व्यापक रूप से उपयोग की जाती हैं। भारत की तेजी से बढ़ती औद्योगिक अर्थव्यवस्था के कारण इन धातुओं की मांग में लगातार वृद्धि हुई है, जबकि खपत की तुलना में घरेलू उत्पादन अभी भी सीमित है। इसलिए, इन धातुओं के एक बड़े हिस्से की पूर्ति आयात के माध्यम से की जाती है। इन धातुओं के रणनीतिक महत्व को देखते हुए, हिमालय के अनुकूल भूगर्भीय क्षेत्रों के भीतर बहु-धातु निक्षेपों (पॉलीमेटेलिक डिपॉज़िट) के लिए व्यवस्थित गवेषण अत्यंत आवश्यक है। इसलिए, मिनरल एक्सप्लोरेशन एंड कंसल्टेंसी लिमिटेड (एमईसीएल) ने भूवैज्ञानिक मानचित्रण (जियोलॉजिकल मैपिंग), भू-रासायनिक नमूनाकरण (जियोकेमिकल सैंपलिंग) और प्रयोगशाला जांच (लैब जांच) के माध्यम से इस क्षेत्र की बहु-धातु खनिज क्षमता (पॉलीमेटैलिक मिनरल पोटेनशियल) का पता लगाने के लिए अमृतपुर ब्लॉक में G-4 स्टेज का आवीक्षण गवेषण शुरू किया है।

1.2.0 ब्लॉक का स्थान और सुगम्यता

अमृतपुर क्षेत्र भारतीय सर्वेक्षण के टोपोशीट संख्या 53O/11 के अंतर्गत आता है। यह 25.77 वर्ग किलोमीटर के क्षेत्र में फैला हुआ है, जिसमें उत्तराखंड राज्य के नैनीताल जिले के निम्नलिखित गाँव और उनके आस-पास के इलाके शामिल हैं। प्रस्तावित ब्लॉक हल्द्वानी से अच्छी तरह जुड़ा हुआ है, जो हल्द्वानी शहर के उत्तर-पूर्व में लगभग 18 किमी की दूरी पर स्थित है और इसके सबसे निकटतम रेलवे स्टेशन काठगोदाम और हल्द्वानी शहर में हैं। नैनीताल का पंतनगर हवाई अड्डा ब्लॉक से लगभग 60 किमी की दूरी पर स्थित निकटतम हवाई अड्डा है। इस क्षेत्र के प्रमुख पर्यटन स्थल भवाली, भीमताल, नौकुचियाताल, सात-ताल और नैनीताल हैं।

तालिका :1.1

अमृतपुर (G-4) क्षेत्र, जिला नैनीताल, उत्तराखंड की ब्लॉक सीमा के मुख्य बिंदुओं के निर्देशांक यहाँ दिए गए हैं।

ब्लॉक के कार्डिनल पॉइंट्स	डेटम: डाब्ल्युजीएस-84				ऊंचाई(मी.)
	भौगोलिक(DD°MM'SS.SS")		यूटीएम क्षेत्र-44(मी.)		
	अक्षांश	देशांतर	पूर्वांग (ईस्टीग)(मी.)	उत्तरांग (नार्थिंग) (मी.)	
A	29°18′46.33″N	79°32′53.02″E	359,001	3,243,525	1093
B	29° 18′ 48.35″ N	79°39′ 07.67″ E	369,109	3,243,466	995
C	29° 17′ 26.38″ N	79° 39′ 09.64″ E	369,134	3,240,942	944
D	29° 17′ 23.00″ N	79° 32′ 53.74″ E	358,989	3,240,959	575

1.3.0 भूविज्ञान

1.3.1 अमृतपुर ब्लॉक **लेसर हिमालय के लिथोटेक्टोनिक डोमेन** के भीतर स्थित है और इसमें पेलियोप्रोटेरोज़ोइक युग की ज्वालामुखीय, अवसादी और अंतर्वेधित चट्टानों का एक विषम मिश्रण (हेट्रोजेनस ऐस्मब्लेज) शामिल है। मुख्य लिथोलॉजिकल इकाईयों में **रायोडासिटिक ज्वालामुखी, फेरुजिनस शेल्स, फेरुजिनस क्वार्ट्ज़ एरेनाइट्स और क्वार्टज़ाइट्स, अल्टर्ड मैफ़िक चट्टानें/एम्फीबोलाइट्स और ग्रेनाइटिक बॉडीज़,** खासकर अमृतपुर ग्रेनाइट शामिल हैं। ये चट्टानें एक ज्वालामुखीय-अवसादी क्रम का प्रतिनिधित्व करती हैं, जिनमें अधीनस्थ मैफिक घटक शामिल हैं। इन चट्टानों में निम्न-स्तरीय कायांतरण और हाइड्रोथर्मल परिवर्तन हुआ है।

1.3.2 संरचनात्मक रूप से, यह क्षेत्र **मेन बाउंड्री थ्रस्ट (एमबीटी) और उससे जुड़े शियर जोन** से प्रभावित है, जिसके कारण हॉस्ट रॉक्स के भीतर फ्रैक्चर, ज्वाईंट्स और विरूपण संरचनाएं (डिफॉर्मेशन फैब्रिक) उत्पन्न हुई हैं। ये संरचनात्मक विशेषताएं, विविध लिथोलॉजिकल बनावट के साथ मिलकर, हाइड्रोथर्मल तरल संचलन और अमृतपुर ब्लॉक के भीतर बहु-धातु खनिजकरण (पॉलीमेटेलिक मिनरलाइजेशन) के विकास के लिए अनुकूल परिस्थितियां प्रदान करती हैं।

1.4.0 **ब्लॉक में खनिजीकरण**

अमृतपुर ब्लॉक में खनिजीकरण का प्रतिनिधित्व संरचनात्मक रूप से नियंत्रित हाइड्रोथर्मल पॉलीमेटेलिक प्रणाली द्वारा किया जाता है जो लेसर हिमालयी ज्वालामुखीय-अवसादी अनुक्रम से संबंधित है। सल्फ़ाइड खनिज जैसे पाइराइट, जिनमें अल्प मात्रा में चाल्कोपाइराइट, गैलेना और पाइरोटाइट होते हैं, परिवर्तित राइओडेसाइटिक ज्वालामुखीय चट्टानों, लौहयुक्त क्वार्ट्ज़ाइट्स और ऐंफिबोलिटिक चट्टानों के भीतर प्रसार, दरारों के भराव और थीन वेन्स के रूप में पाए जाते हैं। खनिजीकरण स्थानिक रूप से फ्रैक्चर नेटवर्कों और मेन बाउंडरी थ्रस्ट विवर्तनिक तंत्र से संबंधित शीयर जोनों से जुड़ा हुआ है, जिन्होंने धातु-वहन करने वाले हाइड्रोथर्मल द्रवों के लिए मार्ग के रूप में कार्य करता है। भू-रासायनिक विश्लेषणों से Cu (>**4900 ppm**), Pb (>**1500 ppm**), Zn (>**900 ppm**), Ag (>**2100 ppb**) **और** Au (>**373 ppb**) के असामान्य सांद्रण का संकेत मिलता है, जो संरचनात्मक रूप से नियंत्रित वेन–स्टॉकवर्क खनिज प्रणालियों के हाइड्रोथर्मल पॉलीमेटेलिक भू-रासायनिक पहचान का संकेत देता है।

1.5.0 **पूर्ववर्ती गवेषण**

1.5.1 अमृतपुर-भीमताल-भोवाली क्षेत्र में पिछले भूवैज्ञानिक कार्यों ने मुख्य रूप से क्षेत्रीय स्तरीकरण, विवर्तनिकी और प्रारंभिक बेस मेटल संकेतों पर ध्यान केंद्रित किया है। **मिडिलमिस (1880,1890)** द्वारा किए गए प्रारंभिक अध्ययनों ने ग्रेनाइट और ज्वालामुखीय चट्टानों के लिथोलॉजिकल संयोजन और जटिल विवर्तनिक संबंधों का दस्तावेजीकरण किया, जबकि **नौटियाल (1943-44)** ने रामगढ़ फॉर्मेशन और संबंधित क्वार्टज़ाइट्स के स्ट्रैटिग्राफिक ढांचे को परिष्कृत किया। **1950-1960** के दशक के दौरान क्षेत्रीय जांचों में **खरकवाल (1951) श्रीवास्तव (1951) पांडे इत्यादि (1963) और रैना और डुंगरकोटी (1966)** ने क्षेत्र में प्राचीन तांबे के कामकाज और सल्फाइड खनिजीकरण की सूचना दी। बाद में, **जांगपांगी इत्यादि (1970)** और **वरादराजन (1978)** द्वारा किए गए भू-रासायनिक और भू-कालिक अध्ययन ने पॉलीमेटेलिक विसंगतियों की पुष्टि की और अमृतपुर ग्रेनाइट की प्राचीन पेलियोप्रोटेरोज़ोइक युग स्थापित की। **शाह इत्यादि. (2012), मंडल इत्यादि. (2019), अग्रवाल इत्यादि. (2021) और कुमार इत्यादि. (2024)** द्वारा की गई हाल की टेक्टोनिक जांचों ने क्षेत्र के संरचनात्मक विकास और धातुजन्य महत्व को स्पष्ट किया है; हालांकि, वर्तमान जांच से पहले अमृतपुर ब्लॉक में व्यवस्थित खनिज गवेषण सीमित रहा।

1.6.0 एमईसीएल द्वारा किया गया गवेषण

1.6.1 वर्तमान में एमईसीएल द्वारा आवीक्षण सर्वेक्षण (रिकॉनिसेंस सर्वे) (G-4) अमृतपुर क्षेत्र में, जिसमें भूवैज्ञानिक मानचित्रण, सतही नमूना संग्रह और प्रयोगशाला अध्ययन शामिल हैं, का उद्देश्य पॉलीमेटैलिक (Cu-Pb-Zn-Ag और Au) खनिजीकरण क्षेत्रों को परिभाषित करना है। दिनांक 19 मई, 2025 को सर्वेक्षण शुरू हुआ और दिनांक 16 अक्टूबर, 2025 को सर्वेक्षण समाप्त हुआ। 25.77 वर्ग किलोमीटर का भूवैज्ञानिक मानचित्रण किया गया और 131 बेडरॉक/ स्ट्रीम अवसाद नमूने एकत्र किए गए। रासायनिक विश्लेषण एएएस, फायर-एसे, आईसीपी-एमएस और एक्सआरएफ के लिए किया गया और खनिज चरण विश्लेषण एक्सआरडी, पेट्रोलॉजिकल और मिनेरोग्राफिक अध्ययनों द्वारा किया गया। सभी नियोजित गतिविधियाँ तालिका 1.2 में विस्तृत रूप से पूरी की गईं, जो अमृतपुर क्षेत्र में प्रगति और गवेषण प्रयासों को प्रदर्शित करती हैं।

1.6.2 गवेषण के उद्देश्य:

1.6.3 गवेषण निम्नलिखित उद्देश्यों के साथ प्रस्तावित है:

क) 1:12,500 पैमाने पर भूवैज्ञानिक मानचित्र की तैयारी।

ख) बेडरॉक के लिए सतही नमूना संग्रहण, जैसे कि वेन्स/सल्फाइड्स से चिप्स/ग्रैब्स और नालों से स्ट्रीम के अवसाद।

ग) बेडरॉक/चैनल सैंपलिंग के माध्यम से आउटक्रॉप्स और संबंधित चट्टानों से खनिजित क्षेत्रों को प्रमाणित करना और उनके क्षैतिज और ऊर्ध्वाधर संबंध का अध्ययन करना।

घ) ब्लॉक को G-3 स्तर पर अपग्रेड करने और ब्लॉक की नीलामी के लिए राज्य सरकार की सुविधा प्रदान के लिए।

1.7.0 भूवैज्ञानिक मानचित्रण और नमूना संग्रहण

1.7.1 अमृतपुर ब्लॉक का विस्तृत भूवैज्ञानिक मानचित्रण 1:12,500 पैमाने पर पूरे ब्लॉक क्षेत्र को कवर करते हुए किया गया ताकि लिथोलॉजिकल यूनिट्स, संरचनात्मक विशेषताओं और हाइड्रोथर्मल परिवर्तन क्षेत्रों को स्पष्ट किया जा सके। मैदानी सर्वेक्षणीय मार्ग का संचालन पहाड़ियों, नदी खंडों, सड़क कटावों और उजागर चट्टानों पर किया गया ताकि शैल-संपर्कों, संरचनात्मक प्रवृत्तियों और खनिजीकरण की विशेषताओं का अभिलेखन किया जा सके। मैपिंग की प्रक्रिया के दौरान, पॉलीमेटेलिक एलिमेंट्स के भू-रासायनिक वितरण का मूल्यांकन करने के लिए रिप्रेजेंटेटिव लिथोलॉजी, परिवर्तित क्षेत्रों, क्वार्ट्ज़ वेन्स और संरचनात्मक रूप से नियंत्रित दरार क्षेत्रों से सिस्टमैटिक बेसरॉक (बीआर) और स्ट्रीम सेडिमेंट/मिट्टी (एसएसएस) नमूने एकत्र किए गए। नमूना कार्यक्रम को असामान्य क्षेत्रों की पहचान करने और ब्लॉक के भीतर लिथोलॉजी और संरचना और खनिजीकरण के बीच संबंध स्थापित करने के लिए डिजाइन किया गया था, और कुल 131 नमूने एकत्र किए गए, जिसमें बेडरॉक और स्ट्रीम सेडिमेंट नमूने शामिल थे।

1.8.0 भूवैज्ञानिक रिपोर्ट तैयार करना

1.8.1 भूवैज्ञानिक रिपोर्ट कॉर्पोरेट कार्यालय, एमईसीएल, नागपुर में खनिजीय और भू-रासायनिक आकड़ा के एकीकरण के द्वारा तैयार की गई थी। विभिन्न मानचित्रों और फ़ोटोग्राफ़ों की तैयारी के लिए ArcGIS, AutoCAD और CorelDraw सॉफ़्टवेयर का उपयोग किया गया और भू-रासायनिक, स्टैटिस्टिकल प्लॉट्स बनाने के लिए पायथन आधारित विश्लेषण का उपयोग किया गया।

तालिका – 1.2:

एमईसीएल द्वारा प्रस्तावित कार्य की मात्रा बनाम वास्तविक उपलब्धि

अमृतपुर क्षेत्र, जिला: नैनीताल, उत्तराखंड

क्रम संख्या	कार्यमद (आईटम)	ईकाई	कार्य की प्रस्तावित मात्रा	प्राप्त हुआ
1.	जियोलॉजिकल मैपिंग (1:12,500 स्केल पर)	वर्ग कि.मी.	25.77 वर्ग कि.मी.	25.77 वर्ग कि.मी.
2.	**बेडरॉक सेम्पलिंग**			
	एएएस विधि द्वारा त्वरित भू-रासायनिक विश्लेषण: Cu-Pb-Zn-Ag	नग	150 (100 Bedrock + 50 Trench	100
	फायरऐस्से द्वारा सोने का विश्लेषण: Au	नग	10	10
	IC-PMS; 34 Elemental Study - As, Sb, Mo, Co, Ni, Sn, Hf, Nb, Ta, Ge, W, Ti, Zr, Se, Te, Cs, Y, Rb, Sr, and REEs: La, Ce,	नग	50	42

	Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu.			
	XRF द्वारा SiO2%, Al2O3%, Fe2O3%, MnO%, MgO%, CaO%, Na2O%, K2O%, P2O5%, TiO2%, SO3%, एवं LOI%	नग	20	20
	एक्सआरडी	नग	10	10
3.	पेट्रोलॉजिकल नमूने	नग	10	10
	क)थीन सेक्सन की तैयारी	नग	10	05
	ख) थीन सेक्सन का अध्ययन	नग	10	05
4.	मिनरलग्राफिकअध्ययन	नग	20	20
	क)पोलिस्ड सेक्सन की तैयारी	नग	20	20
	ख) पोलिस्ड सेक्सन का अध्ययन	नग	20	20
5.	खुदाई (ट्रेंच)	घन.मी.	100	0
6.	रिपोर्ट तैयार करना (डिजिटल फ़ॉर्मेट)	नग	1	1

1.9.0 निष्कर्ष

1.9.1 एमईसीएल ने उत्तराखंड के अमृतपुर क्षेत्र के 25.77 वर्ग किलोमीटर क्षेत्र में पॉलीमेटल्स (Cu-Pb-Zn-Ag और Au तांबा, सीसा, जस्ता, चांदी और सोना) के लिए G-4 स्तर का रिकॉनिसेंस सर्वे किया। अमृतपुर ब्लॉक, लेसर हिमालयी ज्वालामुखी-अवसादी क्रम के साथ जुड़ी एक संरचनात्मक रूप से नियंत्रित हाइड्रोथर्मल पॉलीमेटैलिक खनिज प्रणाली की उपस्थिति को दर्शाता है। भूवैज्ञानिक मानचित्रण पेट्रोग्राफिक और माइनरग्राफिक जांच, और भू-रासायनिक विश्लेषण से पता चलता है हैं कि खनिजकरण मुख्य रूप से रयोडासिटिक ज्वालामुखीय चट्टानों, फेरुजिनस क्वार्टजाइट, परिवर्तित मैफिक चट्टानों और उससे संबंधित ग्रेनाइट बॉडीज़ के भीतर स्थित है, और स्थानिक रूप से मेन बाउंड्री थ्रस्ट टेक्टोनिक रिजीम से संबंधित फ्रैक्चर नेटवर्क और शियर ज़ोन द्वारा नियंत्रित है। हाइड्रोथर्मल परिवर्तन असेंब्लेज़ मुख्य रूप से क्वार्ट्ज–सेरिसाइट–क्लोराइट ± एपिडोट–कार्बोनेट द्वारा नियंत्रित होते हैं और पाइराइट के साथ मामूली कालकोपिराइट और गेलेना जैसे सल्फाइड खनिजों की उपस्थिति महत्वपूर्ण हाइड्रोथर्मल द्रव गतिविधि को दर्शाती है। भू-रासायनिक परिणामों में चुने हुए नमूनों में Cu (>**4900 ppm**), Pb (>**1500 ppm**), Zn (>**900 ppm**), Ag (>**2100 ppb**) **और** Au (>**373 ppb**) की असामान्य सांद्रता दिखाई देती है, जो संरचनात्मक रूप से नियंत्रित हाइड्रोथर्मल वेन–स्टॉकवर्क खनिजीकरण की विशिष्ट पॉलीमेटालिक भू-रासायनिक पहचान का संकेत देती है।

1.10.0 सिफारिश

1.10.1 अनुकूल भूवैज्ञानिक परिवेश, हाइड्रोथर्मल परिवर्तन विशेषताएँ, संरचनात्मक रूप से नियंत्रित सल्फाइड खनिजकरण और वर्तमान जांच के दौरान महत्वपूर्ण पॉलीमेटैलिक भू-रासायनिक विसंगतियों को ध्यान में रखते हुए, अमृतपुर ब्लॉक मुख्य रूप से Cu–Pb–Zn–Ag (तांबा, सीसा, जस्ता, चांदी) के साथ-साथ सहायक Au खनिजकरण के लिए आशाजनक क्षमता प्रदर्शित करता है। अत: यह सलाह दी जाती है कि इस ब्लॉक को G-3 चरण के गवेषण के लिए लिया जाए, जिसमें विस्तृत भूवैज्ञानिक और संरचनात्मक मानचित्रण, व्यवस्थित चैनल और बेडरॉक नमूनाकरण, और पहचाने गए विसंगति क्षेत्रों एवं संरचनात्मक गलियारों में लक्षित गवेषणपूर्ण ड्रिलिंग शामिल हो। इस तरह की जांच खनिज क्षेत्रों की उप-सतही निरंतरता , ज्यामिति और ग्रेड वितरण को स्थापित करने में मदद करेगी और अमृतपुर ब्लॉक में पॉलीमेटैलिक खनिज प्रणाली की आर्थिक क्षमता के मूल्यांकन की सुविधा प्रदान करेगी।

GEOLOGICAL REPORT ON THE RECONNAISSANCE SURVEY (G-4 STAGE) FOR POLYMETALS IN AMRITPUR AREA, NAINITAL

CHAPTER-I

EXECUTIVE SUMMARY

1.1.0 INTRODUCTION

1.1.1 The Amritpur Block is located in the Nainital District of Uttarakhand within the tectonically active Lesser Himalayan region and covers an area of approximately 25.77 sq. km, falling under Survey of India Toposheet No. 53O/11. The block has been taken up for (G-4 stage) reconnaissance survey to evaluate the potential for polymetallic mineralisation comprising copper (Cu), lead (Pb), zinc (Zn) with associated silver (Ag) and gold (Au). Geologically, the area comprises a heterogeneous assemblage of volcanic, sedimentary and granitic rocks, including rhyodacitic volcanics, ferruginous quartzites, altered mafic rocks and granitic bodies, which are structurally influenced by regional tectonic elements such as the Main Boundary Thrust (MBT) and associated shear zones. These lithological and structural conditions provide favourable settings for hydrothermal fluid circulation and mineral deposition.

1.1.2 Base metals such as copper, lead and zinc are essential raw materials for various sectors including electrical and electronic industries, construction, transportation, renewable energy technologies and alloy manufacturing, while precious metals such as silver and gold are widely used in electronics, jewellery, investment and emerging technological applications. India's rapidly growing industrial economy has resulted in increasing demand for these metals, while domestic production remains limited compared to consumption. Consequently, a significant portion of these metals is met through imports. In view of the strategic importance of these metals, systematic exploration for polymetallic deposits within favourable geological terrains of the Himalaya is essential. Accordingly, Mineral Exploration and Consultancy Limited (MECL) has undertaken (G-4 stage) reconnaissance survey in the Amritpur Block to evaluate the polymetallic mineral potential of the area through geological mapping, geochemical sampling and laboratory investigations.

1.2.0 LOCATION AND ACCESSIBILITY OF THE BLOCK

1.2.1 The Amritpur Area falls in Survey of India Toposheet No. 53O/11 and covers an area of 25.77 sq.km in and around villages Amritpur, Salri, Amiya, Ranibagh, Basuli, Harki, Banana, Haida-Khaan, Pinshela of District Nainital, State Uttarakhand. The proposed block is well connected from Haldwani situated approximately 18 km to the north east of Haldwani, with nearest railway stations in the Kathgodam and Haldwani city. Pantanagar Airport of Nainital is the nearest airport about 60 km away from the block. The important tourist places are Bhowali, Bhimtal, Nauchukiataal, Saat-taal, Nainital.

Table 1.1:
Co-ordinates of Cardinal Points of the block boundary of Amritpur (G-4) Area.
Dist.: Nainital, Uttarakhand

Block Cardinal Points	Datum: WGS-84				Elevation (m)
	Geographic (DD°MM'SS.SS")		UTM Zone-44 (m)		
	Latitude	Longitude	Easting (m)	Northing (m)	
A	29° 18′ 46.33″ N	79° 32′ 53.02″ E	359,001	3,243,525	1093
B	29° 18′ 48.35″ N	79° 39′ 07.67″ E	369,109	3,243,466	995
C	29° 17′ 26.38″ N	79° 39′ 09.64″ E	369,134	3,240,942	944
D	29° 17′ 23.00″ N	79° 32′ 53.74″ E	358,989	3,240,959	575

1.3.0 GEOLOGY

1.3.1 The Amritpur Block is situated within the **Lesser Himalayan lithotectonic domain** and comprises a heterogeneous assemblage of volcanic, sedimentary and intrusive rocks of Paleoproterozoic age. The principal lithological units include **rhyodacitic volcanics, ferruginous shales, ferruginous quartz arenites and quartzites, altered mafic rocks/amphibolites and granitic bodies**, particularly the Amritpur Granite. These rocks represent a volcanic–sedimentary sequence with subordinate mafic components that have undergone low-grade metamorphism and hydrothermal alteration.

1.3.2 Structurally, the area is influenced by the **Main Boundary Thrust (MBT) and associated shear zones**, which have produced fractures, joints and deformation fabrics within the host rocks. These structural features, together with the varied lithological assemblage, provide favourable conditions for hydrothermal fluid circulation and the development of polymetallic mineralisation within the Amritpur Block.

1.4.0 MINERALISATION IN THE BLOCK

1.4.1 Mineralisation in the Amritpur Block is represented by a structurally controlled hydrothermal polymetallic system associated with the Lesser Himalayan volcanic–sedimentary sequence. Sulphide minerals such as pyrite with minor chalcopyrite, galena and pyrrhotite occur as disseminations, fracture fillings and thin veins within altered rhyodacitic volcanics, ferruginous quartzites and amphibolitic rocks. The mineralisation is spatially associated with fracture networks and shear zones related to the Main Boundary Thrust tectonic regime, which acted as conduits for metal-bearing hydrothermal fluids. Geochemical analyses indicate anomalous concentrations of Cu (>**4900 ppm**), Pb (>**1500 ppm**), Zn (>**900 ppm**), Ag (>**2100 ppb**) and Au (>**373 ppb**), suggesting a hydrothermal polymetallic geochemical signature typical of structurally controlled vein–stockwork mineral systems.

1.5.0 PREVIOUS EXPLORATION

1.5.1 Previous geological work in the Amritpur–Bhimtal–Bhowali region has mainly focused on regional stratigraphy, tectonics and preliminary base metal indications. Early studies by **Middlemiss (1880, 1890)** documented the lithological assemblages and complex tectonic relationships of granitic and volcanic rocks, while **Nautiyal (1943–44)** refined the stratigraphic framework of the Ramgarh Formation and associated quartzites. Regional investigations during the **1950s–1960s** by **Kharakwal (1951), Srivastava (1951), Pande et al. (1963)** and **Raina and Dungrakoti (1966)** reported ancient copper workings and sulphide mineralisation in the area. Later geochemical and geochronological studies by **Jangpangi et al. (1970)** and **Varadarajan (1978)** confirmed polymetallic anomalies and established the Paleoproterozoic age of the Amritpur Granite. More recent tectonic investigations by **Shah et al. (2012), Mandal et al. (2019), Agarwal et al. (2021)** and **Kumar et al. (2024)** have further clarified the structural evolution and metallogenic significance of the region; however, systematic mineral exploration in the Amritpur Block remained limited prior to the present investigation.

1.6.0 EXPLORATION CARRIED OUT BY MECL

1.6.1 The present Reconnaissance Survey (G-4) in the Amritpur Area by MECL, including geological mapping, surface sampling, and laboratory studies, aims to delineate Polymetallic (Cu-Pb-Zn-Ag & Au) mineralization zones. The survey commenced on 19th May 2025 and concluded on 16th Oct 2025. Geological Mapping of 25.77 sq. km and 131 bedrock/Stream Sediments samples were collected. Chemical analysis was done for AAS, Fire-Assay, ICP-MS and XRF and Mineral Phase analysis was done by XRD, petrological & Mineragraphic studies. All planned activities were achieved as detailed in Table 1.2, showcasing progress and exploration efforts in the Amritpur Area.

1.6.2 **Objective of Exploration:**

1.6.3 The exploration is proposed with the following objectives:

a) Preparation of Geological map on 1:12,500 Scale.
b) Surface Sampling for bedrock as Chips/grabs from veins/sulphides and Stream sediments from nallas.
c) To prove the mineralized zones by bedrock/channel sampling from outcrops and associated rocks and to study their lateral and vertical relationship.
d) To upgrade the block to G-3 level and facilitate the state govt. for auctioning of the block.

1.7.0 GEOLOGICAL MAPPING AND SAMPLING

1.7.1 Detailed geological mapping of the Amritpur Block was carried out on 1:12,500 scale covering the entire block area to delineate lithological units, structural features and zones of hydrothermal alteration. Field traverses were conducted along ridges, stream sections, road cuttings and exposed outcrops to record lithological contacts, structural attitudes and mineralisation features. During the course of mapping, systematic bedrock (BR) and stream sediment/soil (SSS) samples were collected from representative lithologies, altered zones, quartz veins and structurally controlled fracture zones to evaluate the geochemical distribution of polymetallic elements. The sampling programme was designed to identify anomalous zones and to establish the relationship between lithology, structure and mineralisation within the block and a total of 131 samples were collected, from bedrock and stream sediments samples.

1.8.0 PREPARATION OF GEOLOGICAL REPORT

1.8.1 Geological report was prepared in Corporate Office, MECL, Nagpur by integration of geological and geochemical data. ArcGIS, AutoCAD and CorelDraw software were used for preparation of various maps and photographs and Python based analysis has been used for generating geochemical, statistical plots.

Table – 1.2:

Proposed Quantum of Work vs. Actual achievement by MECL in Amritpur Area, District: Nainital, Uttarakhand

Sl. No.	Item of Work	Unit	Proposed Quantum of work	Achievement
1	Geological Mapping (on 1:12,500 Scale)	Sq. km	25.77 Sq. Km	25.77 Sq. Km
2	**Chemical Analysis**			
	Rapid Geochemical Analysis by AAS method: Cu-Pb-Zn-Ag	Nos	150 (100 Bedrock + 50Trench	100 Bedrock
	Gold Analysis by Fire-assay: Au	Nos	10	10
	IC-PMS; 34 Elemental Study - As, Sb, Mo, Co, Ni, Sn, Hf, Nb, Ta, Ge, W, Ti, Zr, Se, Te, Cs, Y, Rb, Sr, and REEs: La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu.	Nos	50	42
	Major Oxide: SiO2%, Al2O3%, Fe2O3%, MnO%, MgO%, CaO%, Na2O%, K2O%, P2O5%, TiO2%, SO3%, & LOI% by XRF	Nos	20	20
	External Check of Cu-Pb-Zn-Ag	No	15	10
	External Check for Au	No	1	1
	External Check for ICPMS	No	5	4
	External Check for Major Oxide	No	2	2
	XRD	Nos	10	10
3	Petrological Samples	Nos	10	10
	a) Preparation of Thin Section	Nos	10	10
	b) Study of Thin Section	Nos	10	10
4	Mineragraphic Study	Nos	20	20
	a) Preparation of Polished Section	Nos	20	20
	b) Study of Polished Section	Nos	20	20
5	Excavation (Trench)	Cu. m.	100	0
6	Report Preparation (Digital Format)	Nos.	1	1

1.9.0 CONCLUSION

1.9.1 MECL carried out G-4 level reconnaissance survey for Polymetals (Cu-Pb-Zn-Ag & Au) in 25.77 sq.km area of Amritpur Area of Uttarakhand. The Amritpur Block, indicates the presence of a structurally controlled hydrothermal polymetallic mineral system associated with the Lesser Himalayan volcanic–sedimentary sequence. Geological mapping, petrographic and mineragraphic investigations, and geochemical analyses suggest that the mineralisation is hosted within rhyodacitic volcanics, ferruginous quartzites, altered mafic rocks and associated granitic bodies, and is spatially controlled by fracture networks and shear zones related to the Main Boundary Thrust tectonic regime. Hydrothermal alteration assemblages dominated by quartz–sericite–chlorite ± epidote–carbonate and the occurrence of sulphide minerals such as pyrite with minor chalcopyrite and galena indicate significant hydrothermal fluid activity. Geochemical results reveal anomalous concentrations of Cu (>**4900 ppm**), Pb (>**1500 ppm**), Zn (>**900 ppm**), Ag (>**2100 ppb**) and Au (>**373 ppb**) in selected samples, suggesting a polymetallic geochemical signature typical of structurally controlled hydrothermal vein–stockwork mineralisation.

1.10.0 RECOMMENDATIONS

1.10.1 Considering the favourable geological setting, hydrothermal alteration characteristics, structurally controlled sulphide mineralisation and significant polymetallic geochemical anomalies observed during the present investigation, the Amritpur Block shows promising potential for Cu–Pb–Zn–Ag with subordinate Au mineralisation. It is therefore recommended that the block be taken up for **G-3 stage exploration**, involving detailed geological and structural mapping, systematic channel and bedrock sampling, and targeted exploratory drilling across identified anomaly zones and structural corridors. Such investigations will help in establishing the subsurface continuity, geometry and grade distribution of the mineralised zones and will facilitate the evaluation of the economic potential of the polymetallic mineral system in the Amritpur Block.

CHAPTER-2

2.1.0 DETAILS OF THE QUALIFIED PERSON(S) / EXPLORATION AGENCY

TITLE	DETAILS
(a) Name:	MINERAL EXPLORATION AND CONSULTANCY LIMITED (Formerly Mineral Exploration Corporation Limited) (A Govt. of India Enterprise; A Miniratna-I PSE) (Ministry of Mines, Govt of India)
(b) Communication Address:	Mineral Exploration and Consultancy Limited Highland Drive Road, Seminary Hills, Nagpur-440006. Maharashtra
(c) Contact Mobile No:	0712-2510289, 0712-2511829
(d) E-Mail id:	gm-exploration@mecl.gov.in
(e) Qualification of Technical Personnel	M.Sc. Geology/Applied Geology/M. Tech (Geo-Exploration)
(f) Experience:	Professionals have more than 30+ years of experience
(g) Affiliation to any organization/company, if yes, specify the name of the organization or company.	-

2.2.0 PERSONNEL ASSOCIATED IN EXPLORATION WORK

2.2.1 The list of personnel associated with the execution of different exploration activities carried out in Amritpur Area (G-4), District: Nainital, Uttarakhand is given in the Table No. 2.2.

Table-2.2: List of Personnel associated with Exploration Work

S No.	Title	Name of the Personnel
1	Overall Guidance	Shri Shrikant Sharma, HOD (Exploration/NEM)
2	Overall planning, Coordination & Supervision	Shri Shrikant Sharma, HOD (Exploration/NEM)
		Shri Swarup Dhara, Sr. Manager (Geology)
3	Project Management	Shri Yashu Joshi, Asst. Manager (Geology)
4	Physical Execution of Work	
	Geology	Shri Yashu Joshi, Asst. Manager (Geology)
		Miss Talisenla LongKumer, ET (Geology)
5	Chemical Laboratory	Shri Shrikant Sharma, HOD (Exploration/NEM)
		Shri Rohit Sharma, Sr. Manager (Chemical)
		Shri Deepti Rahangdale, Sr. Manager (Chemical)
		Shri Bojana, Manager (Chemical)
		Shri Piyush Kanti Mahanti, Manager (Chemical)
		Fawaz Asstt, Manager (Chemical)
6	Petrographic studies	Shri Sayantan Pal, Manager (Geology)
7	Documentation	Shri Yashu Joshi, Asst. Manager (Geology)
8	Hindi Translation	Shri Srikant rai, Sr. Hindi Officer

2.3.0 ACKNOWLEDGEMENT

2.2.1 MECL express their sincere gratitude to the following individuals and organizations for their valuable contributions and support throughout this reconnaissance survey (G-4) for Polymetals (Cu-Pb-Zn-Ag & Au) exploration in the Amritpur Area, Nainital. We extend our heartfelt appreciation to Mr. Brijesh Kumar Sant (IAS), 'Director General' of Geology and Mining Unit, and Mr. Anil Kumar, 'Additional Director' and Dinesh Kumar HoD, DGM, Uttarakhand for their continuous support in facilitating logistics arrangements and official liaison work, ensuring the successful execution of the fieldwork. We would also like to acknowledge the local communities in the villages of Amritpur Village, Salari and Rani-bagh area in the Block, for their co-operation which facilitated our field operations smoothly. Finally, we extend our appreciation to all those who have directly or indirectly contributed to the successful completion of this reconnaissance survey, whose names may have been inadvertently omitted.

CHAPTER-3
TITLE AND OWNERSHIP

3.1.0 TITLE OF THE REPORT:

GEOLOGICAL REPORT ON THE RECONNAISSANCE SURVEY (G-4 STAGE) FOR POLYMETALS IN AMRITPUR AREA, NAINITAL

Table – 3.1:

Table Showing Ownership of Amritpur Area (G-4), District: Nainital, Uttarakhand

(i) Name of the explorer/Mining or prospecting rights holder.	Mineral Exploration and Consultancy limited, NMEDT and The Office of Directorate of Geology & Mining, Uttarakhand.
Address:	*Directorate of Geology and Mining, Bhopalpani Grant (Kadaikhala), Raipur-Thano Airport Motor Road, P.O. Dhanyari, District: Nainital, PIN-248008, Uttarakhand, India.*
Telephone No.	9622346843
E-Mail id:	dir.ukdgm@gmail.com
(ii) Details of period of prospecting/mineral right if any:	Field Session: May 2025 to October 2025
In case of a license or lease:	NA
(a) Date of grant:	NA
(b) Date of execution:	NA
(c) Period of license or lease:	NA
(d) Date of completion	NA

CHAPTER-4
DETAILS OF THE AREA

4.1.0 LOCATION AND ACCESSIBILITY OF THE BLOCK

4.1.1 The Amritpur Block is situated in Nainital District, Uttarakhand, within the Lesser Himalayan foothill zone, covering an area of 25.77 sq. km. The block is located within Survey of India Toposheet No. 53O/11 and falls administratively under the Haldwani–Kathgodam tehsil. The surrounding villages include Amritpur, Salri, Amiya, Ranibagh, Pinrao, Dahara, and Basuli, which represent a predominantly rural setting characterized by agriculture, forestry, and small habitations. The block is characterized by its position in the geologically fragile outer Lesser Himalayan zone, with elevations ranging from approximately 800 to 1,500 meters above mean sea level.

4.1.2 The district of Nainital spans a total geographical area of 4,251 sq. km, with Amritpur Block representing a significant micro-region within this expansive Lesser Himalayan terrain. The block lies approximately 39 km south of Nainital district headquarters, towards Haldwani and Kathgodam, along the NH-109 corridor, providing regional connectivity while retaining a semi-rural landscape.

4.1.3 The proximity of the block to Haldwani city, a major commercial and administrative centre of the Kumaun region, with a population of 364,129 (Census 2011) distributed across both urban and rural settlements, facilitates access to essential services, logistics, and field support infrastructure. Kathgodam Railway Station, the nearest broad-gauge railway terminus of the Northern Railway network, is located at a distance of approximately 6 km from the block. Pantnagar Airport, providing limited domestic air connectivity, is situated at a distance of about 60 km. The block is also located close to prominent tourist destinations such as Nainital, Bhimtal, Naukuchiatal, Sattal, and Haldwani, which contributes to regional socio-economic activity.

4.1.4 Access to the block is primarily through a combination of state highways and local motorable roads. The Kathgodam–Ranibagh (Bhimtal–Haldwani) State Highway serves as the principal transportation corridor in the area. Additional access is provided by the Amritpur–Banna–Babiyad motor road and the Bhimtal–Naukuchiatal motor road, which ensure year-round connectivity to nearby settlements. However, the road network is vulnerable to disruption during the south-west monsoon season, when heavy rainfall frequently triggers slope failures, hill cracking, and landslides, leading to temporary road closures and the need for recurring maintenance.

4.1.5 Geologically, the area lies within a tectonically active Himalayan zone, where steep slopes, high relief, and intense rainfall contribute to natural instability. Consequently, any exploration or future mineral development activities in the block require careful planning and phased implementation, with due consideration to environmental sensitivity, slope stability, and land-use constraints.

Table 4.1:

Co-ordinates of Cardinal Points of the block boundary of Amritpur (G-4) Area. Dist.: Nainital, Uttarakhand

Block Cardinal Points	Datum: WGS-84				Elevation (m)
	Geographic (DD°MM'SS.SS")		UTM Zone-44 (m)		
	Latitude	Longitude	Easting (m)	Northing (m)	
A	29° 18′ 46.33″ N	79° 32′ 53.02″ E	359,001	3,243,525	1093
B	29° 18′ 48.35″ N	79° 39′ 7.67″ E	369,109	3,243,466	995
C	29° 17′ 26.38″ N	79° 39′ 9.64″ E	369,134	3,240,942	944
D	29° 17′ 23.00″ N	79° 32′ 53.74″ E	358,989	3,240,959	575

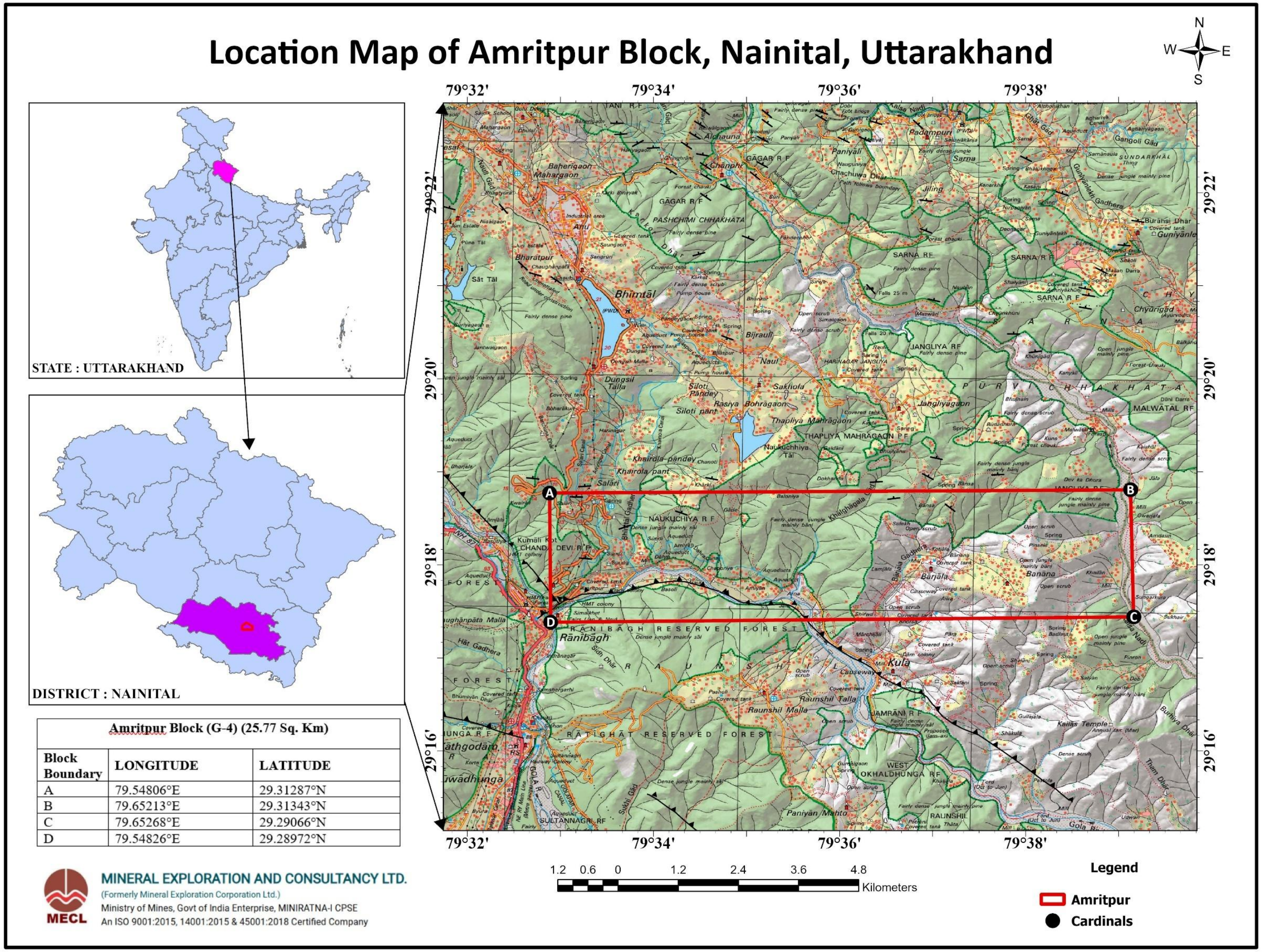
4.2.0 DETAILS OF THE AREA WITH LAND USE

4.2.1 The Amritpur Block does not fall within any notified eco-sensitive zone or wildlife sanctuary, and no ASI-protected monuments are present within the block area. A significant portion of the block is covered by forest land, interspersed with village settlements and agricultural patches. The Lesser Himalayan terrain within the block is characterized by rugged topography, steep slopes, dense vegetation, and deeply incised drainage, making it susceptible to landslides, particularly during seasonal climatic variations.

4.2.2 The block is free from any major or minor mineral mining leases at present. Existing land use is primarily limited to forestry, agriculture, and habitation, with no active mining or industrial operations recorded within the block boundary.

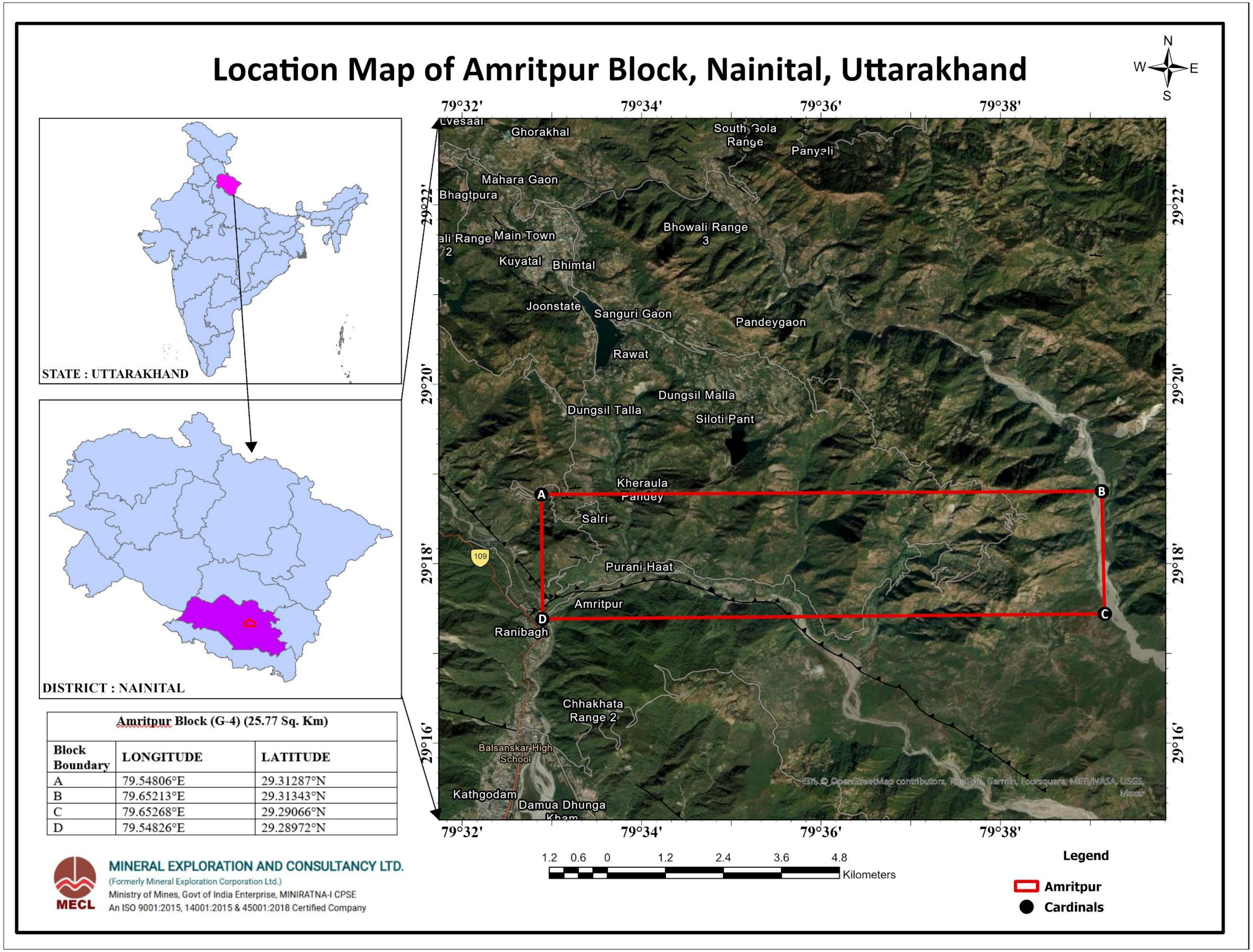
4.3.0 MINERAL(S) UNDER INVESTIGATION

4.3.1 The Amritpur Block has been taken up for reconnaissance-level exploration (G-4) for polymetallic mineralization, with specific focus on base metals (Copper, Lead, and Zinc) along with associated Silver and Gold (Cu-Pb-Zn ± Ag-Au), based on regional geological, structural, and geochemical indications.



Amritpur Block (G-4) (25.77 Sq. Km)		
Block Boundary	LONGITUDE	LATITUDE
A	79.54806°E	29.31287°N
B	79.65213°E	29.31343°N
C	79.65268°E	29.29066°N
D	79.54826°E	29.28972°N

Text Figure 4.1: Location Map (Toposheet) of Amritpur Area for Polymetals (Cu-Pb-Zn-Ag & Au), District- Nainital, Uttarakhand



Amritpur Block (G-4) (25.77 Sq. Km)		
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A	79.54806°E	29.31287°N
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C	79.65268°E	29.29066°N
D	79.54826°E	29.28972°N

Text Figure 4.2: Location Map (Google Map) of Amritpur Area for Polymetals (Cu-Pb-Zn-Ag & Au), District- Nainital, Uttarakhand

CHAPTER-5

PHYSIOGRAPHY AND ENVIRONMENT

5.1.0 RELIEF OF THE AREA WITH MINIMUM AND MAXIMUM ELEVATION, DRAINAGE PATTERN, NATURAL WATER COURSES, RESERVOIRS, ETC.

5.1.1 The Amritpur Block is situated in the Lesser Himalayan physiographic province of the Kumaun Himalaya, forming part of the Himalayan foothill belt. The terrain is characteristically rugged and mountainous, marked by steep slopes, narrow ridges, deeply incised valleys, and high local relief. The physiography reflects the young and tectonically active nature of the Himalayan orogen, where continuous uplift, erosion, and slope modification are dominant geomorphic processes.

5.1.2 Elevation within the block varies significantly, ranging from approximately 400 m above mean sea level in the southern foothill zones to higher elevations exceeding 1,500–2,000 m along ridges and hilltops in the northern and central parts of the block. The relief is controlled by lithology, structural fabric, and intense fluvial incision, resulting in V-shaped valleys and steep escarpments.

5.1.3 The drainage pattern of the area is predominantly dendritic to sub-parallel, governed by lithological variations and structural trends. Seasonal and perennial streams originate from higher elevations and flow generally towards the south and south-east, ultimately joining major river systems such as the Gaula and Kosi rivers. Stream gradients are steep, and discharge shows strong seasonal variation, with peak flows occurring during the southwest monsoon period.

5.1.4 The geomorphology of the block is influenced by active tectonics, high rainfall, and weathering of fractured rocks, making the area prone to slope instability, landslides, and soil erosion, particularly during periods of intense precipitation. These physiographic characteristics impose natural constraints on access, land use, and field operations.

5.1.5 The climate of the Amritpur Block is sub-tropical to temperate, influenced by altitude and monsoonal circulation. Summers are generally mild to warm in the lower reaches, while higher elevations experience comparatively cooler conditions. Winters extend from November to March, with cold conditions prevailing at higher altitudes and occasional frost or light snowfall in elevated areas.

5.1.6 The area receives moderate to high annual rainfall, averaging between 1,500 mm and 2,000 mm, most of which occurs during the southwest monsoon season (June to September). Intense monsoonal rainfall frequently triggers landslides, debris flows, and temporary disruption of surface connectivity. The post-monsoon and winter periods are relatively dry, offering favourable conditions for field-based geological investigations.

5.1.7 Soil cover within the block varies with topography and lithology. Lower slopes and valley floors are characterized by colluvial and alluvial soils, whereas higher elevations exhibit thin, residual, and rocky soils developed over quartzites, schists, and granitic lithologies. In many areas, bedrock exposure is prominent due to active erosion and limited soil development.

5.1.8 Loose overburden, weathered rock material, and slope wash deposits are common on steep slopes and along drainage channels, contributing to slope instability during periods of heavy rainfall.

5.2.0 FLORA & FAUNA

5.2.1 A significant portion of the Amritpur Block is covered by forest vegetation, typical of the Lesser Himalayan belt. The vegetation includes mixed forests comprising Sal, Chir Pine, Oak, Deodar, Burans (Rhododendron), and associated undergrowth, with variation corresponding to altitude and aspect.

5.2.2 Dense vegetation cover, while contributing to slope stability in some areas, also limits surface exposure of bedrock, thereby influencing geological mapping and sampling density during exploration activities.

5.2.3 The block does not fall within any notified eco-sensitive zone, wildlife sanctuary, or national park, and no protected monuments or heritage sites are reported within the block boundary. Existing land use is primarily limited to forestry, agriculture, and village habitation, with no active mining operations.

5.2.4 The block does not fall within any notified eco-sensitive zone, wildlife sanctuary, or national park, and no protected monuments or heritage sites are reported within the block boundary. Existing land use is primarily limited to forestry, agriculture, and village habitation, with no active mining operations.

5.2.5 The region represents a geologically and ecologically sensitive Himalayan environment, where natural processes such as erosion, landslides, and seasonal hydrological variations play a significant role. Consequently, reconnaissance-stage exploration activities must be conducted with due consideration to environmental safeguards, slope stability, and minimal surface disturbance.

5.2.6 At the G-4 stage, exploration activities are limited to surface geological mapping, sampling, and minor trenching, which are not expected to cause any significant or irreversible environmental impact when carried out following standard environmental and safety practices.

5.3.0 ROADS, RAILWAY TRACK, ELECTRIC TRANSMISSION LINE, TELEPHONE LINE, ETC.

5.3.1 The Amritpur Block is reasonably well connected to regional infrastructure through a network of state highways and local motorable roads. The Kathgodam–Ranibagh (Bhimtal–Haldwani) State Highway serves as the principal transportation corridor in the vicinity of the block and provides connectivity to Haldwani, Kathgodam, Bhimtal, and Nainital. In addition, internal access to the block is facilitated by local metalled and semi-metalled roads such as the Amritpur–Banna–Babiyad motor road and the Bhimtal–Naukuchiatal motor road, which connect nearby villages and agricultural areas.

5.3.2 The nearest railway station is Kathgodam Railway Station, located at an approximate distance of 6 km from the block. Kathgodam functions as a major railhead for the Kumaun region and provides regular passenger and freight connectivity to major urban centres, including Delhi and Lucknow, thereby supporting logistical requirements for exploration activities.

5.3.3 Electric power supply to villages in and around the Amritpur Block is provided through the state electricity distribution network, with overhead electric transmission and distribution lines traversing nearby habitations and road corridors. The area is serviced by the state electricity grid, with 11 kV and 33 kV transmission lines running parallel to the major road corridors. These transmission lines primarily serve domestic and agricultural needs and are not expected to pose any constraint to reconnaissance-level exploration activities.

5.3.4 Telecommunication facilities in the area include mobile network coverage provided by major service operators, although signal strength may vary locally due to rugged terrain and dense vegetation. Landline telephone infrastructure is limited and largely restricted to settled areas. Overall, basic communication facilities are available to support field operations, subject to local terrain-related limitations.

5.4.0 HOST POPULATION (LOCAL TRIBES), HUMAN SETTLEMENTS WITHIN AND NEARBY THE AREA

5.4.1 The Amritpur Block falls under the Haldwani–Kathgodam tehsil of Nainital District, characterized by a predominantly rural population distributed across small villages and hamlets. The prominent settlements in and around the block include Amritpur, Salri, Amiya, Ranibagh, Pinrao, Dahara, and Basuli.

5.4.2 The According to Census 2011 data, Amritpur village comprises approximately 350 households with a total population of 1,480 (786 males and 694 females). The population density is moderate, concentrated along the valley floors and lower slopes. While the region is not a designated Tribal Belt, Census data records a marginal Scheduled Tribe (ST) population of approximately 22 individuals (1.5%), with a Scheduled Caste (SC) population of 163 individuals (~11%). The populace is primarily engaged in mixed agrarian-horticultural activities and service-sector employment in nearby urban hubs.

5.5.0 SOCIO DEMOGRAPHIC PROFILE OF THE AREA AND NEARBY

5.5.1 The socio-demographic profile of the area reflects the broader characteristics of rural Nainital District, with moderate population density and a livelihood pattern largely dependent on agriculture and allied activities. The nearby urban centre of Haldwani acts as a major commercial and service hub, providing access to markets, healthcare, education, and administrative facilities.

5.5.2 Literacy levels in the district are relatively high compared to national rural averages, and basic amenities such as primary schools, healthcare centres, and local markets are available in nearby settlements. Seasonal migration to Haldwani and other urban centres for employment is common. The socio-economic setting does not pose any significant constraint to reconnaissance-level exploration activities.

5.6.0 HISTORICAL SITES AND ARCHAEOLOGICAL MONUMENTS, PLACES OF WORSHIP, PUBLIC UTILITIES ETC.

5.6.1 No Archaeological Survey of India (ASI)–protected monuments or notified heritage structures are reported within the Amritpur Block. The surrounding region, however, contains culturally significant towns such as Nainital and Bhimtal, which are known for historical temples and colonial-era structures.

5.6.2 Local places of worship, including small temples and community shrines, are present within nearby villages and settlements. Public utilities such as schools, primary healthcare centres, and community buildings are located outside the block area, mainly along established habitation zones and road networks.

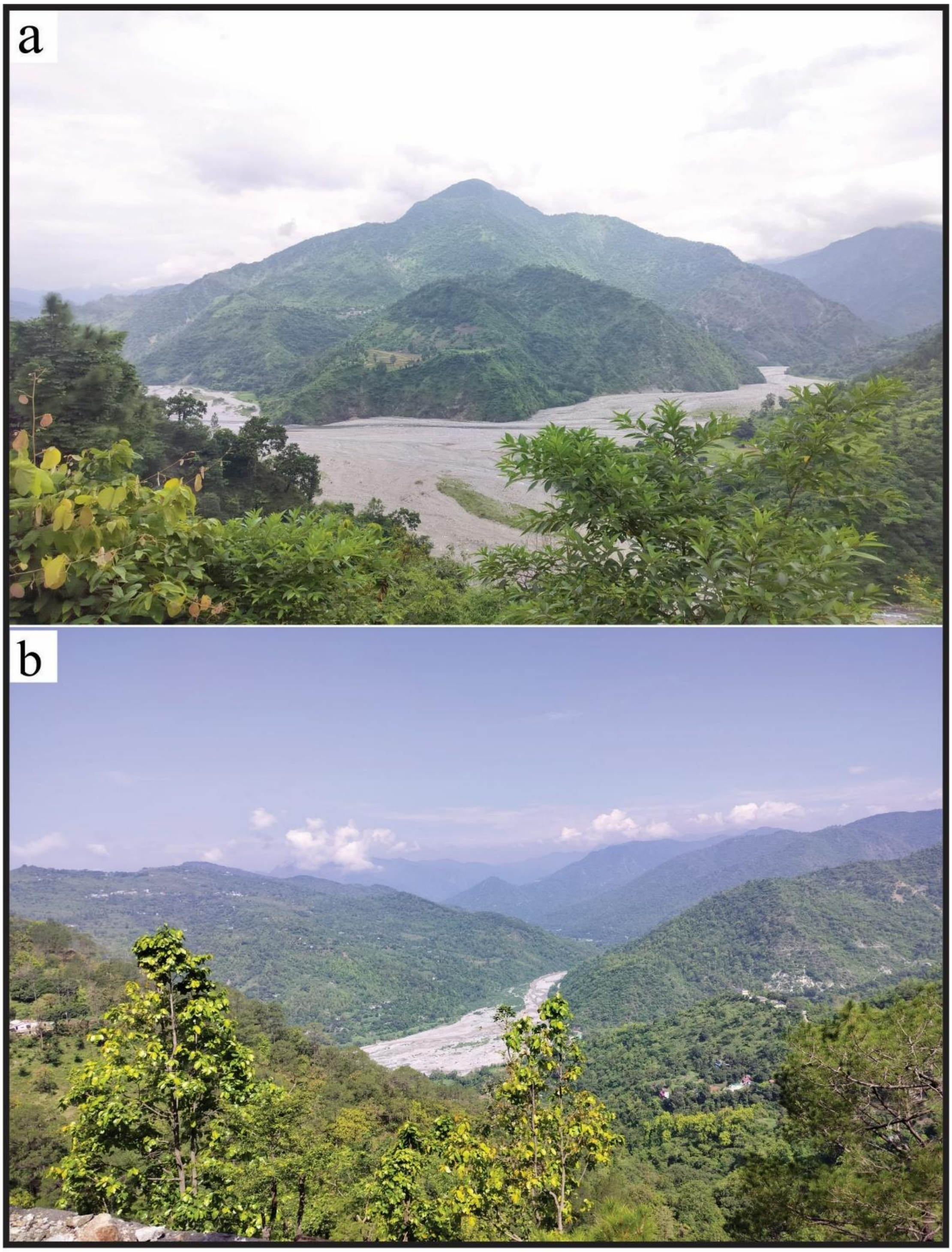
5.6.3 Regarding public utilities, Amritpur Area, being part of Nainital district, has basic infrastructure in place. This includes primary health centers, government schools, and local administrative offices. However, the extent of these facilities varies on the specific location within the block, with areas closer to Haldwani city potentially having better access to public services.

5.6.4 The village's near to Haldwani city have access more advanced facilities in the urban center for healthcare, education, and other public services. However, the challenging terrain and road conditions in Amritpur Area affects the ease of access to these urban amenities for far villages.

5.7.0 FORESTS, SANCTUARIES, NATIONAL PARK AND WILD LIFE SANCTUARIES ETC.

5.7.1 The Amritpur Block does not fall within any notified national park, wildlife sanctuary, or eco-sensitive zone. A substantial portion of the block is, however, covered by forest land, forming part of the Lesser Himalayan forest belt.

5.7.2 No major or minor mineral mining leases are reported within the block, and the area remains largely undisturbed from industrial activity. Exploration activities at the G-4 stage are planned to be conducted in compliance with applicable forest and environnemental régulations.



Photograph-5.1: a). & b). A wide, open river channel of the Gaula River is observed at West and central part the block, developed due to the Main Boundary Thrust (MBT) traversing along the river course.

5.8.0 FLORA AND FAUNA WITHIN AND NEARBY

5.8.1 The block and its surrounding areas support vegetation typical of the Lesser Himalayan region, comprising mixed forests of Sal (*Shorea robusta*), Chir/Pine (*Pinus roxburghii*), Banj/Oak (*Quercus leucotrichophora*), Deodar, Burans (Rhododendron), and associated shrubs and grasses. Vegetation density varies with altitude, slope orientation, and soil cover. The flora of the area predominantly features subtropical moist deciduous forests. Common tree species likely include Sal (Shorea robusta), Teak (Tectona grandis), and various species of Oak and Pines. The understorey is often rich in shrubs, ferns, and herbs. In the higher elevations, one might find rhododendron species, a unique flower of Uttarakhand and have high medicinal values. The region is also known for its medicinal plants, which have been traditionally used in Ayurvedic practices.

5.8.2 The faunal diversity represents a transition zone between the Terai and Lesser Himalaya. Common mammalian species include the Barking Deer (Muntiacus muntjak), Wild Boar (Sus scrofa), Rhesus Macaque, and occasional Leopards (Panthera pardus) that venture from adjacent forest tracts. The avian population is diverse, featuring species typical of the Himalayan foothills.

5.9.0 WATER BODIES SUCH AS RIVER, NALA, STREAM, RESERVOIR, ETC

5.9.1 The hydrological regime is dominated by the Gaula River, a rain-fed perennial river that serves as the major source of surface water for the Haldwani region. The river bed at Amritpur is characterized by massive boulders and cobbles derived from the upstream granitic terrain.

5.9.2 The area contains no major natural lakes within the block boundaries; however, the significant tectonic lakes of the region—Bhimtal, Naukuchiatal, and Sattal—are located within a 5–10 km radius to the northeast. These water bodies influence the regional microclimate and groundwater table but are hydro-geologically distinct from the immediate block area.The flow and volume of these water bodies vary significantly between the monsoon and dry seasons. The terrain is highly susceptible to rapid changes due to factors like rainfall and landslides.

5.10.0 CLIMATIC CONDITIONS

5.10.1 There are mainly four main Seasons, Winter (December to February), Spring (March to April), Summer (May to June), Monsoon (July to September), Autumn (October to November) serves as a transitional period. The area experiences mountain and valley breezes typical of hilly regions. These local wind systems can influence daily temperature fluctuations and weather patterns.

5.10.2 The climate of the Amritpur Block is classified as Sub-tropical to Warm Temperate, exhibiting distinct seasonal variations.

5.10.2.1 **Temperature**: The mean annual temperature is approximately 22.7°C. Summers (April–June) are warm with maximum temperatures reaching 30–35°C, while winters (December–February) are cool, with minimum temperatures dropping to 2–7°C. Due to its elevation, the area generally experiences milder temperatures compared to the plains.

5.10.2.2 **Rainfall**: The area experiences a monsoonal climate with heavy precipitation. The average annual rainfall varies between 1,600 mm and 1,900 mm, with the heaviest precipitation recorded during July and August. Even during the dry season, the area may experience occasional rainfall due to its proximity to the mountains.

5.10.2.3 **Humidity**: Relative humidity remains high (>70%) during the monsoon season and moderate (40–50%) during the dry pre-summer months. Humidity levels are generally moderate to high, especially during and immediately after the monsoon season. The winter months tend to be drier.

5.11.0 OTHER PHYSIOGRAPHIC, SOCIAL AND ENVIRONMENTAL FACTOR

5.11.1 The topography of the area influences local microclimates, vegetation patterns, and land use. The area likely features a mix of gentle slopes and steeper hillsides, with potential for soil erosion during heavy rains. The geology of the region, typical of the Siwalik range, and includes sedimentary rocks and alluvial deposits.

5.11.2 Seismic Sensitivity: The block lies in Zone IV/V of the Seismic Zoning Map of India, attributed to its proximity to the active Main Boundary Thrust (MBT). This necessitates stringent adherence to seismic safety codes for any future infrastructure development.

5.11.3 Landslide Susceptibility: The combination of steep slopes, fractured Amritpur Granite, and high monsoonal rainfall renders certain road corridors and slope faces susceptible to landslides and debris flows.

5.11.4 The block's environment is shaped by its forest cover, water resources, and human activities. The area may face challenges related to balancing development needs with preserving local ecosystems, ensuring sustainable use of springs and streams, particularly important given the area's reliance on these water sources. Potential alterations in rainfall patterns or temperature regimes could affect local agriculture and ecosystems, and during monsoons erosion is a major issue due to the hilly terrain.

5.11.5 Environmental Impact of Exploration: The proposed G-4 stage exploration involves low-impact activities such as geological mapping and surface sampling. These activities are transient in nature and are not anticipated to generate significant environmental externalities or disrupt the socio-ecological fabric of the local community.

CHAPTER-6
INFRASTRUCTURE

6.1.0 LOCAL INFRASTRUCTURE WITH ROADS, RAILWAYS, PORT FACILITIES, ELECTRICITY, WATER.

6.1.1 The Amritpur Block is located in Nainital District, Uttarakhand, within the Lesser Himalayan foothills. The area is characterized by challenging terrain with significant topographic relief, which directly influences the accessibility and quality of road infrastructure. The block's road network comprises single-lane narrow metaled roads that serve as vital lifelines for local communities and potential exploration activities.

6.1.2 The Nainital-Bhimtal metaled road passes in proximity to the block and functions as a crucial transportation corridor connecting the Amritpur Block with Nainital city (approximately 30-35 km away) and other major urban centres such as Almora and Ranikhet. This primary route facilitates the movement of personnel, equipment, and supplies essential for both exploration and potential future mining operations. Additionally, secondary metaled roads and motorable tracks branch off from this main artery, providing access to various villages within and surrounding the block, including settlements such as Amritpur, Salari and Amiya.

6.1.3 The road faces significant maintenance challenges, particularly during the monsoon season (July-September). The region's high rainfall (averaging 2,000-2,200 mm annually, with peak precipitation during monsoon months) combined with the area's geological composition of shale, phyllite, schist, and other highly fractured rocks with intense pore-pressure, creates conditions conducive to slope failures and landslides. Heavy rains frequently trigger mass movements along cut slopes adjacent to roads, necessitating regular and often expensive repairs and maintenance. The block remains accessible throughout the year, although rock may get blocked and travel times may be substantially increased during peak monsoon periods.

6.1.4 The Amritpur Block does not have direct railway connectivity. The nearest operational railway station is located at Kathgodam, approximately 8-10 km south of the block, on the main broad-gauge railway line, serves as another major railway junction providing connectivity to major cities including Delhi, and eastern India. Periodic narrow-gauge heritage rail services operate on limited sections in the region, but these are primarily for tourist purposes and do not contribute to freight or mineral transportation infrastructure relevant to exploration or mining operations.

6.1.5 Amritpur Block, being a landlocked area situated in the interior Himalayan region, does not have access to any port facilities. The nearest major seaports serving northern India are located on the Arabian Sea (western coast) and Bay of Bengal (eastern coast), both of which are more than 1,500-2000 kilometres away. This geographic constraint necessitates that any mineral commodities produced from the block would require transportation via road and/or rail over considerable distances to reach export terminals or distant processing centres, thereby affecting the overall economic viability of mining operations.

6.1.6 The Amritpur Block is connected to the national power grid through a network of electricity transmission and distribution lines managed by the Uttarakhand Power Corporation Limited (UPCL). The primary power supply to villages within and adjacent to the block originates from regional power plants and hydroelectric installations (including facilities such as the Bhimtal Hydroelectric Project and other schemes in the Kumaon region), supplemented by power from the national grid. However, due to the hilly terrain and occasional extreme weather conditions, power supply face interruptions, especially in more remote parts of the block. Some areas rely on local transformers and distribution networks.

6.1.7 Water availability and supply in the Amritpur Block is characterized by abundant natural water sources due to the region's orographic precipitation and the presence of numerous springs, streams, and seasonal nalas (small waterways). The block is traversed by several perennial and seasonal water courses, with the primary drainage system being the Gaula River (also known locally as Gola River or Baigul River in its lower course). The Gaula River originates in the Lesser Himalayas near Paharpani village in the Nainital district and flows southward through the region. The river is fed by numerous tributary streams originating from the surrounding hills and forests, including significant tributaries such as Gangoligad, Kalshagad, Kaligad, and Balianala, which contribute to its perennial flow throughout the year. After flowing approximately 60 kilometers through the Lesser Himalayan foothills, the Gaula River enters the Bhabhar and Terai plains near Kathgodam and Haldwani, where it ultimately joins the Ramganga River (a tributary of the Ganges River). The Gaula River is primarily a spring-fed river and serves as the primary water source for Haldwani city and surrounding settlements. The Gaula Barrage, located at Kathgodam, provides drinking water supply and irrigation for the Bhabhar agricultural fields (Kaur, 2023).

6.1.8 Water supply in Haldwani and surrounding areas, including the Amritpur region, is managed by Uttarakhand Jal Sansthan (UJS) and Uttarakhand Pey Jal Nigam (UPJN). The system currently provides an average of 92 liters per capita per day against the national standard of 135 liters per capita per day. Groundwater sources supplement municipal supplies, with aquifer mapping by the Central Ground Water Board identifying resources across Haldwani and Ramnagar blocks. For settlements beyond piped water coverage, hand pumps, bore wells, and dug wells managed by local gram panchayats serve household and livestock needs. Seasonal water scarcity occurs during pre-monsoon periods (April-June), and the region benefits from ongoing augmentation projects under the Uttarakhand Integrated and Resilient Urban Development Project (UIRUDP) with Asian Development Bank financing, aimed at improving supply reliability and service coverage by 2030.

6.1.9 The Amritpur Area, situated in the Kumaun Himalayan region, is geologically sensitive and prone to man-induced disaster events (Kaira et al., 2023). The area faces a range of natural disasters, including earthquakes, landslides, heavy rains, floods, flash floods, cloudbursts, and forest fires, due to the uneven relief, mountainous terrain, slope instability, and erratic heavy rainfall (Kaira et al., 2023).

6.1.10 The Uttarakhand Disaster Management Authority (USDMA) has classified significant portions of the Nainital district as moderate-to-high risk zones for multiple hazards. Any large-scale industrial development or mining activity would necessitate:

A. Comprehensive Disaster Risk Assessment and Management Plans
B. Structural engineering safeguards against seismic activity
C. Slope stability management and early warning systems for landslides
D. Storm water management infrastructure to mitigate flood risks
E. Emergency preparedness and response protocols

6.2.0 The adoption of solar-based systems, such as solar trees, has been explored as a clean energy solution for the mountainous region, emphasizing the importance of sustainable energy practices (Kumar et al., 2021).

Photograph 6.1: (a) Metalled road network within the block, covering only about 20–30% of the area with relatively well-maintained roads; (b) occurrence of stone falling and slope instability during the monsoon season; (c) pedestrian (kaccha) pathways connecting villages within the block, present only at a few locations and covering less than 5–10% of the total block area; and (d) approximately 60–70% of the road network remains damaged or poorly maintained, particularly due to

CHAPTER-7

GEOLOGY OF THE AREA

7.1.0 BRIEF REGIONAL GEOLOGY OF THE AREA OUTLINING THE BROAD GEOLOGICAL, STRATIGRAPHICAL AND STRUCTURAL FRAME WORK.

7.1.1 The Amritpur Block exploration area encompasses approximately 25.77 square kilometres in Nainital District of Uttarakhand, situated within the Kumaun Lesser Himalaya of the collisional Himalayan orogen. The area is characterized by Paleoproterozoic metamorphic and crystalline rocks, specifically the Amritpur Granite, intruded into metamorphic rocks of the Jaunsar Group. These Precambrian rocks are overlain to the south by Neogene molassic sediments of the Siwalik Group, with the contact defined by the Main Boundary Thrust (MBT). The exploration area represents a critical example of the structural and compositional complexity of the outer Lesser Himalayan metasedimentary and crystalline sequences bound by major crustal-scale fault systems.

7.2.0 REGIONAL GEOLOGY

7.2.1 The Amritpur exploration area occupies a position within the outer Kumaun Lesser Himalaya, positioned between the Main Boundary Thrust (MBT) to the south and the Salari Thrust to the north. The Kumaun Himalayan segment extends between the Sutlej River to the west and the Kali River to the east, representing a major transect of the collisional Himalayan belt. Continental collision between the Indian and Eurasian plates initiated during the Paleocene-Eocene, approximately 40-45 million years ago (Oliver et. al. 2013), resulting in sustained crustal shortening, thickening, and metamorphic transformation of both continental margins.

7.2.2 The Himalayan orogen is subdivided into four lithotectonic zones from south to north: the Sub-Himalaya (comprising the Siwalik Group), the Lesser Himalaya, the Greater Himalaya, and the Tethyan Himalaya, separated by major crustal-scale fault systems. The Amritpur area specifically occupies the outer Lesser Himalayan metasedimentary and crystalline sequence, bounded by the MBT to the south and the Salari Thrust to the north. The geological evolution of this zone reflects episodic crustal assembly, with Paleoproterozoic magmatic rocks (approximately 1900 Ma) representing significant components of the northernmost part of the Indian lithospheric plate that were incorporated into the orogenic framework during subsequent Himalayan tectonism.

Table 7.1
CHRONO-STRATIGRAPHICAL ORDER OF LESSER HIMALAYAN AREA
(After Mandal et al., 2019)

Age	Formation	Lithology
Ediacaran	Krol Formation	Black and red shale, sandstone, cherty limestone
Cryogenian	Blaini Formation	Gray and black shale, sandstone, and dolomite
Neoproterozoic	Nagthat Formation	Muddy sandstone
<800 Ma	Chandpur Formation	Muddy sandstone and mudstone
~1860 Ma	Rautgara Formation (Bhowali Quartzite & Bhimtal Volcanics equivalent)	Quartzite, mafic sill, volcanic rocks
1900 ± 100 Ma	Amritpur Granite	Granite-granodiorite augen gneiss
Paleoproterozoic	Ramgarh Formation	Schists, gneisses, quartz-feldspar porphyry

7.2.3 The stratigraphic succession of the area is underlain by a Paleoproterozoic metamorphic basement, the Ramgarh Formation, composed chiefly of schists, gneisses and quartz–feldspar porphyries that constitute the primary structural and lithological framework of the block. Intrusion of the Amritpur Granite (crystallization age 1900 ± 100 Ma) into this basement represents a major syn-kinematic magmatic event and a primary control on later metallogenic processes. Overlying supracrustal assemblages include the Rautgara Formation (correlative with the Bhowali Quartzite and Bhimtal Volcanics; ~1860 Ma), characterised by quartzitic units intercalated with mafic sills and volcanic flows indicative of extensional, arc-related to back-arc volcanism. A younger Neoproterozoic siliciclastic package, represented by the Chandpur and Nagthat formations (<800 Ma), records terrigenous deposition under relatively quiescent conditions, succeeded by Cryogenian (Blaini Formation: shales, sandstones and dolomites) and terminal Proterozoic (Ediacaran Krol Formation: black/red shales, sandstones and cherty limestones) shallow-marine sequences. This stratigraphic record, from Paleoproterozoic basement and syn-kinematic granitism through successive supracrustal units, has been overprinted by Himalayan deformation and metamorphism; the resultant structural architecture and thermal history provide the principal controls on hydrothermal fluid migration, structural trap formation and the observed polymetallic (Cu–Pb–Zn ± Ag–Au) mineralization potential of the Amritpur area.

7.2.4 **Amritpur Granite:** The Amritpur Granite Body (AGB) is tectonically positioned between the Jaunsar Group metasediments to the north and the MBT to the south, forming a key structural unit in the outer Lesser Himalaya. U-Pb zircon geochronology indicates that the Amritpur Granite is composite in nature, with primary intrusion during the Middle Proterozoic at approximately 1888 ± 46 Ma (^{87}Rb-^{87}Sr whole rock age), and a younger leucocratic component with ages of approximately 1200-1600 Ma. Earlier potassium-argon dating of the Amritpur Granite yielded ages of 1880 ± 40 m.y. (muscovite) and 1330 ± 40 m.y. (biotite), confirming the composite nature and multiple phases of crystallization and remobilization.

7.2.5 Fission-track thermochronology reveals rapid cooling and exhumation of the AGB from basement depths during the middle Miocene. Apatite fission-track (AFT) ages from the AGB range from 11.3 to 14.7 Ma (mean ~13.4 Ma), while zircon fission-track (ZFT) ages range from 12.4 to 15.4 Ma (mean ~13.9 Ma). These ages document rapid cooling and exhumation of the AGB from estimated basement depths of approximately 8-10 kilometers during the middle Miocene (~14-13 Ma), with exhumation rates estimated at approximately 1-2 mm/year. Mean AFT and ZFT ages show similar trends from the MBT to the Salari Thrust, indicating sustained rapid uplift and exhumation of the AGB along the MBT during the middle Miocene.

7.2.6 The Amritpur Granite is interpreted as having been exhumed to the surface from basement depths as "Tectonic Slivers" during the development and reactivation of the MBT between Miocene to Pliocene periods. Morphometric and structural analysis indicate that the AGB has lower erosion susceptibility compared to rocks north of the body, with alignment along regional faults (MBT and Salari Thrust) and dendritic drainage patterns suggesting relatively low susceptibility to erosion. Scattered seismic activity patterns indicate that dominant tectonic activity along the MBT almost ceased after the Pliocene-Quaternary period, though Quaternary reactivation is indicated by paleolake deposits and landform features in the region.

7.2.7 Paleoproterozoic magmatism in the Himalayan region is episodic, spanning from Paleoproterozoic through Cenozoic with distinct episodes recording different tectonic settings and crustal processes. The Amritpur Granite, dated to approximately 1900 ± 100 Ma, represents a significant Paleoproterozoic magmatic body in the outer Lesser

Himalaya with important implications for understanding crustal evolution of the northern Indian plate.

7.2.8 Anisotropy of magnetic susceptibility (AMS) analysis of the Amritpur Granite reveals that despite the apparent lack of penetrative macroscopic tectonic fabric in hand samples, the granite exhibits evidence of subtle grain-scale deformation. The granite is classified as S-type (peraluminous) based on its mineralogical characteristics and geochemical signatures, indicating an origin through crustal melting rather than mantle-derived magmatism. The presence of K-feldspar megacrysts and the compositional nature of the granites indicate a porphyritic to equigranular texture reflecting shallow to intermediate-depth emplacement.

7.3.0 REGIONAL STRUCTURE

7.3.1 The regional structure is dominated by north-dipping, south-vergent thrust sheets characteristic of the Himalayan fold-and-thrust belt. The principal structural features controlling the geology of the Amritpur region are the Main Boundary Thrust (MBT), the Salari Thrust, the Ramgarh Thrust, the Main Central Thrust (MCT) to the north, and subordinate structures including subsidiary tear faults and transverse shear zones. These structures define a contractional tectonics regime with primary compression-oriented north-south to north-northeast-south-southwest.

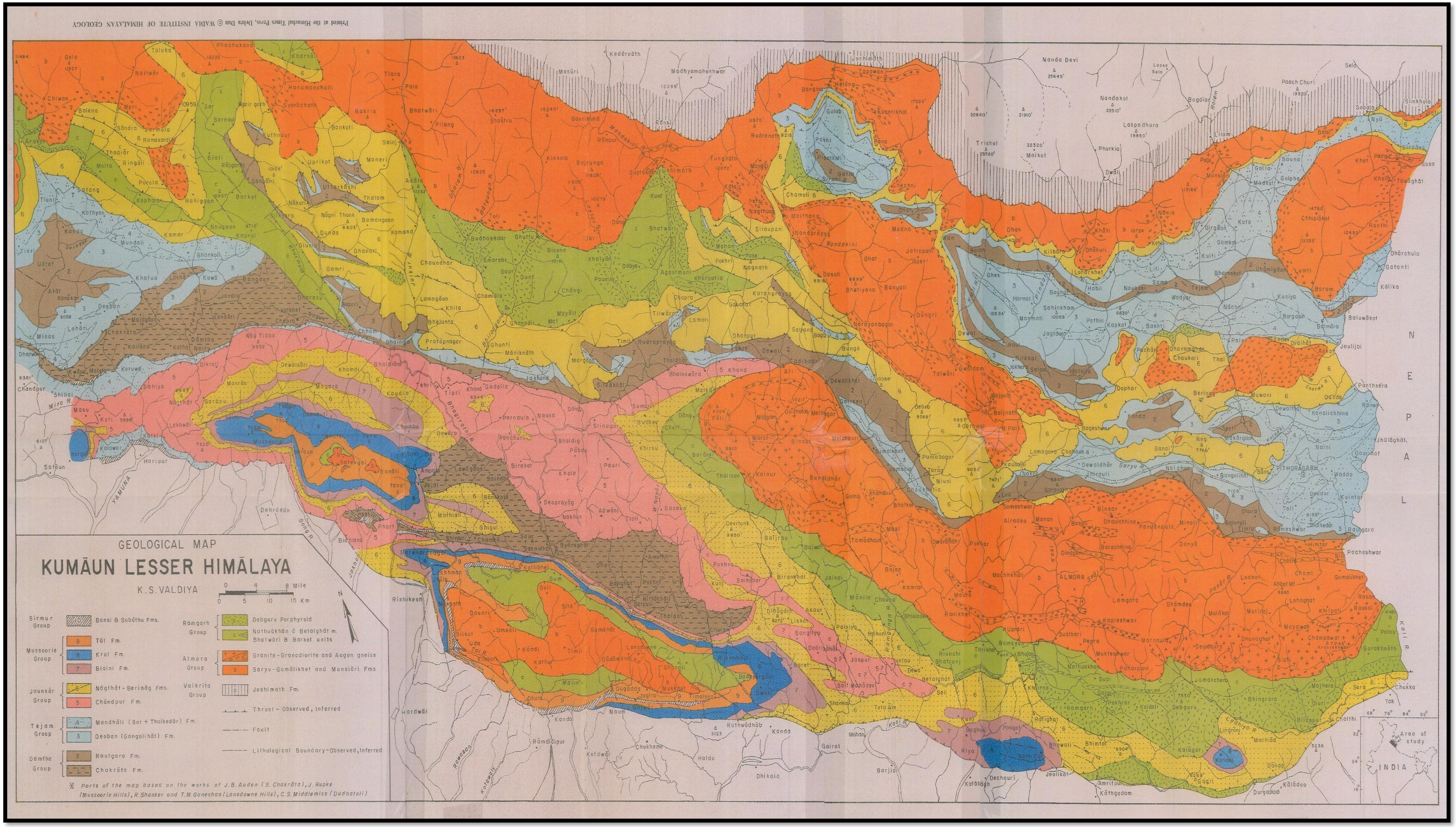
7.3.2 **Main Boundary Thrust (MBT):** The MBT represents the southernmost major tectonic discontinuity in the Amritpur area, separating Sub-Himalayan Neogene Siwalik molasse in the footwall from Lesser Himalayan Proterozoic crystalline and metasedimentary rocks in the hanging wall. In the Gaula–Ranibagh sector, the MBT is expressed as a ~100 m thick fault damage zone composed of multiple imbricate fault slices and ductile shear zones, indicating intense strain localization. Structural analyses document sinistral transpressional kinematics, combining strike-slip motion with N–S to NNE–SSW shortening, attributed to an oblique/lateral ramp geometry of the thrust. Thermochronological constraints (AFT ages ~4.4–5.5 Ma) indicate Pliocene–Quaternary reactivation, associated with rapid exhumation and cooling of the thrust zone. Although presently locked, the MBT remains a major crustal-scale structure controlling deformation, exhumation, and seismic hazard in the foothill region.

7.3.3 **Salari Thrust:** The Salari Thrust bounds the Amritpur Granite to the north, separating it from metamorphic rocks of the Jaunsar Group. This structure represents an important subsidiary thrust that controls the contact between the Amritpur Granite body and the overlying Lower Jaunsar Group volcanic-sedimentary sequence. The Salari Thrust exhibits the structural characteristics typical of Lesser Himalayan thrust zones, with evidence of ductile deformation at depth and brittle reactivation in the Quaternary. Mean AFT and ZFT ages from the AGB show similar trends from the MBT to the Salari Thrust, indicating sustained exhumation along this fault zone during the same middle Miocene episode that affected the MBT.

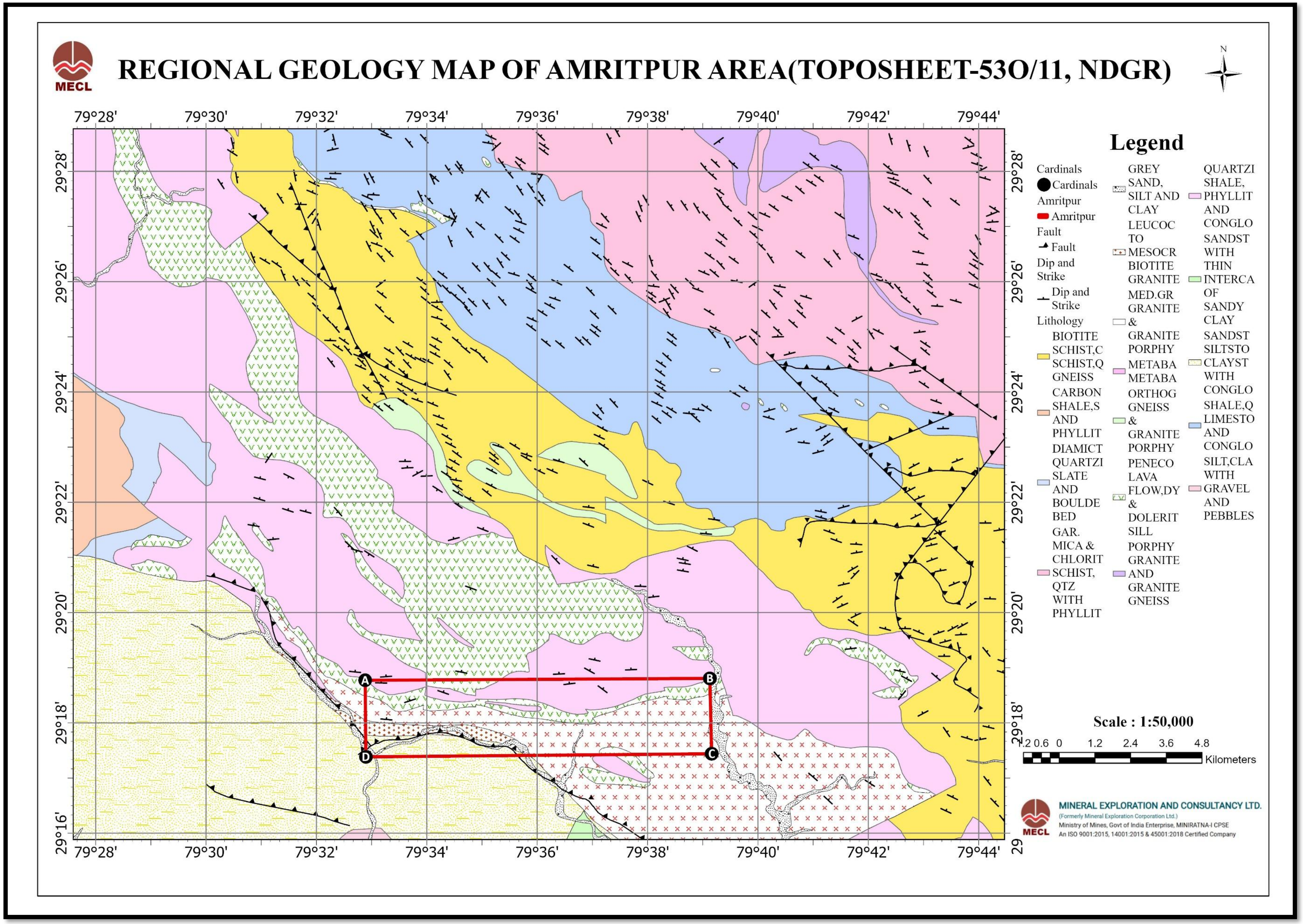
7.3.4 **Main Central Thrust (MCT) and Lesser Himalayan Duplex:** The MCT, located further north of the Amritpur area, represents a major crustal-scale boundary separating the Lesser Himalayan Sequence from the Greater Himalayan Crystalline Complex. Regionally, the Lesser Himalaya is organized into a hinterland-dipping duplex system, consisting of stacked thrust sheets that accommodated large-magnitude shortening during India–Asia collision. The MCT records a long-lived history of ductile shearing, metamorphism, and crustal thickening, marking the primary tectonic interface between Indian continental crust and higher-grade Himalayan rocks. Although not exposed within the immediate Amritpur Block, the MCT and associated duplex architecture exert a first-order control on regional stress distribution, thrust kinematics, and exhumation patterns across the Kumaun Lesser Himalaya.

7.4.0 REGIONAL MINERALIZATION

7.2.1 Mineralization in the Kumaun Lesser Himalaya shows polymetallic sulphide assemblages occurring as disseminations, vein-filling assemblages, and deposits within metasedimentary and granitic host rocks (Sharma and Rao, 2008), with particular concentrations near fault zones and boundaries between lithologies of contrasting competency (Shah et al., 2012; Mandal et al., 2016). The largest known polymetallic deposit in the northwest Himalaya is the Askot polymetallic (Cu-Zn-Pb ± Ag ± Au) sulphide deposit located in the easternmost edge of the Askot klippe in Pithoragarh District, Uttarakhand, with an estimated resource of 3.06 million tonnes at 1.91% Cu, 4.7% Zn, 3.5% Pb, 0.35 g/t Au and 37.71 g/t Ag (Indian Bureau of Mines, 2015). This volcanogenic massive sulphide (VMS) deposit formed during Proterozoic extensional tectonics, with sulphide mineralization hosted within chlorite-biotite-muscovite schists, tuffaceous (sericitic) schists, and biotite-augen gneisses that are intensively altered (Mandal et al., 2016). The mineralization forms massive, lenticular sulphide lenses with an average thickness of 2.5 m and strike length of 645 m, reflecting modification during Himalayan deformation and metamorphism.



Text Figure 7.1 : Geological Map of Kumaun Lesser Himalayas, Valdiya (1980)



Text Figure 7.2 : Regional Geological Map of Amritpur Area, Dist: Nainital & Almora (1:50,000, After GSI).

7.5.0 LOCAL GEOLOGICAL SETTING DETAILING THE COMMON ROCK TYPES, CONTROLS OF MINERALIZATION, DETAILS OF OLD WORKINGS IF ANY, SURFACE EXPOSURES.

7.5.1 The area predominantly comprises rocks of the Bhimtal Volcanics and Bhowali Quartzite normally overlies the Amritpur Granite. The local stratigraphic succession is as below (After Mandal et al., 2019).

Table- 7.2: Litho-stratigraphic classification of Amritpur Area.

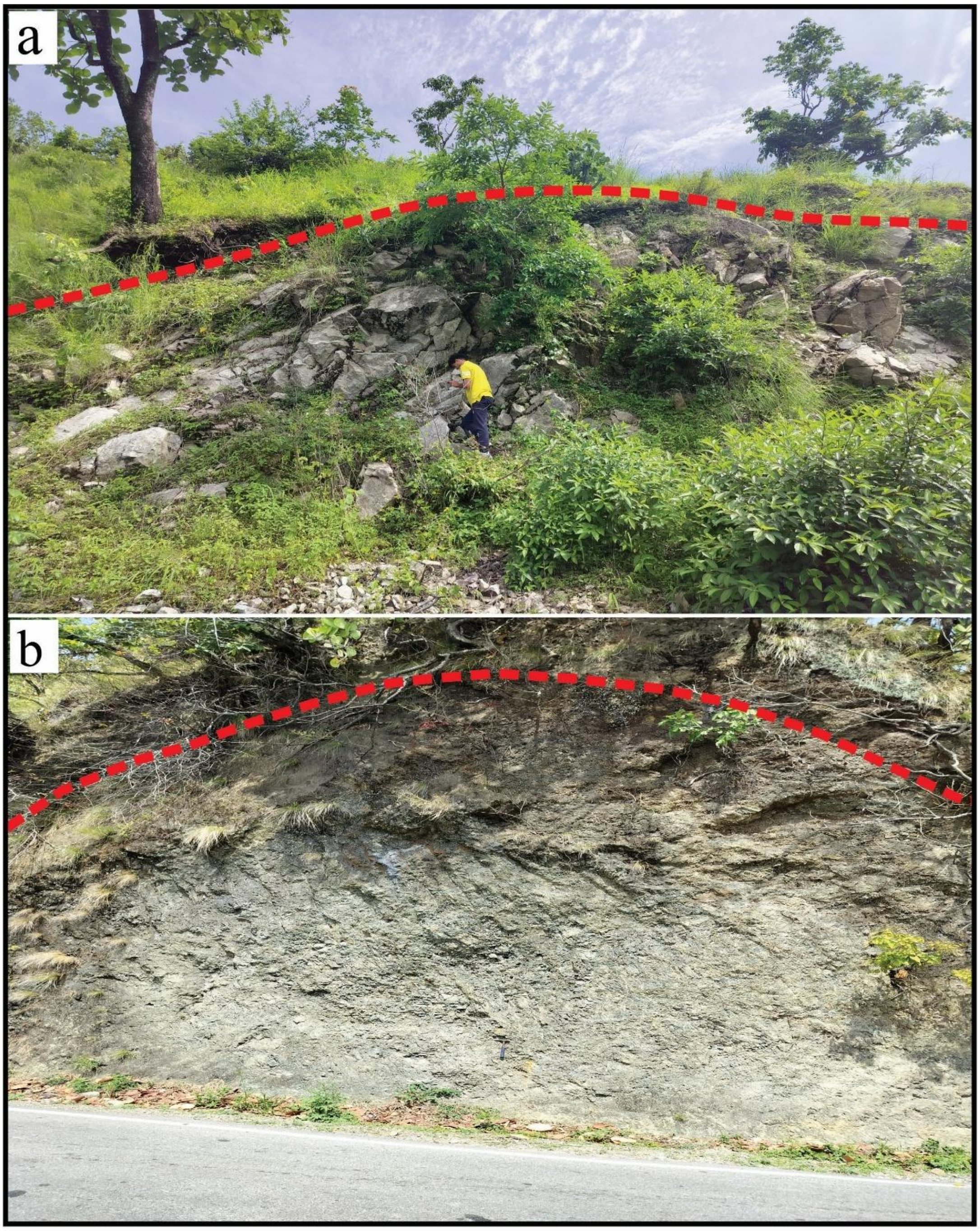
(After Mandal et al., 2019)

Age	Formation	Lithology
Miocene	Middle Siwalikh	Sandstone-Shale Intercalations.
Neoproterozoic	Nagthat Formation	Quartzite & Muddy sandstone
~1860 Ma	Rautgara Formation (Bhowali Quartzite & Bhimtal Volcanics equivalent)	Quartzite, mafic sill, volcanic rocks
1900 ± 100 Ma	Amritpur Granite	Granite-granodiorite augen gneiss

7.5.2 The Amritpur Area is part of the Lesser Himalayas, which is bounded by two major tectonic features: the Main Boundary Thrust (MBT) and the Ramgarh Thrust (NRT) (Valdiya, 1980). The Main Boundary Thrust, which is tectonically and seismically active at present, marks the boundary between the Shivalik and lesser Himalayas. The Ramgarh Thrust, on the other hand, constitutes the boundary between the Lesser and Almora crystalline complex, with a distinct change in the style and orientation of structures, as well as the grade of metamorphism.

7.6.0 DESCRIPTION OF ROCK TYPES

The lithological units encountered in the Amritpur Block exhibit a complex interplay of sedimentary, magmatic, and metamorphic characteristics. Litho-units mapped in the block include Quartzite, Meta-Basalts, Amphibolites, Chlorite Schist, Rhyodacite, Biotite/Phlogopite Granite, Sandstone/Quartz Arenite (Siwalikhs), and channels of alluvium. Shale/Slate, Siltstone, are also observed as thin layers intercalated with the Quartzites and Meta-Basalts, which are not mappable units. The field descriptions below are corroborated by petrographic studies and mineragraphic analysis.

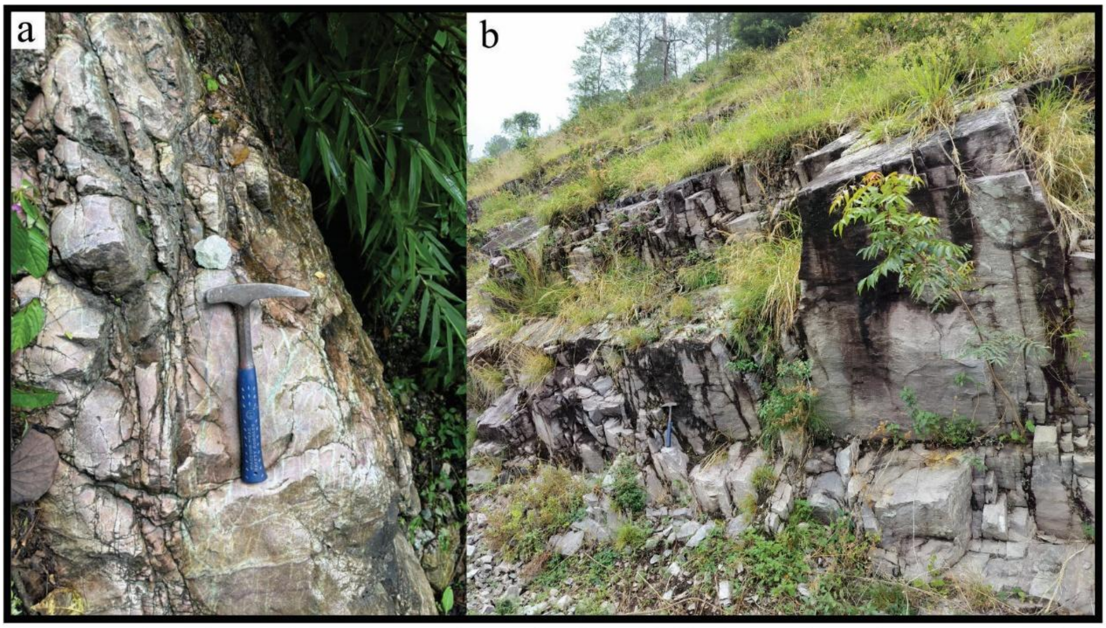


Photograph 7.1: a). Thin Layer of Soil over Granite outcrop holding trees, b). A layer of soil is exposed in road section, at the central part of the block.

7.6.1 TOP SOIL

The top soil in the Amritpur Block is generally thin and discontinuous, with thickness varying from a few centimetres to about 0.5–1.0 m, depending on slope, vegetation cover, and geomorphic position. The heavy rainfall conditions of the area, results in extreme weathering conditions of the area, leading to most of the rocks to soil, most of the top soil. It comprises brown to reddish-brown silty to clayey soil, locally mixed with angular to subangular rock fragments derived from in-situ weathering of underlying lithologies. In valley floors and gentler slopes, colluvial and slope-wash deposits are developed, whereas on steep hill slopes the soil cover is sparse to absent, exposing bedrock. The soil is ferruginous in places and supports moderate to dense forest vegetation.

The morphology of the hills/ridges are gentle to steep sloping ridges. The area exhibits sufficient thickness of soil cover on steep slopes. The river valleys/nallas/piedmont areas are covered with alluvium and debris/scree. Alluvium/scree are fresh debris, which eroded and falls annually on monsoons period. The shape of the grain ranges from subrounded to rounded in river valleys, while angular at piedmont /slopes, indicating minimal transportation of grains within the block and representing the in-situ conditions of the block's geology.



Photograph 7.2 : a). Nearly vertical dipping Pink Quartzite with multiple fine Quartz veins. b). Thick Bedding of Massive White Quartzite

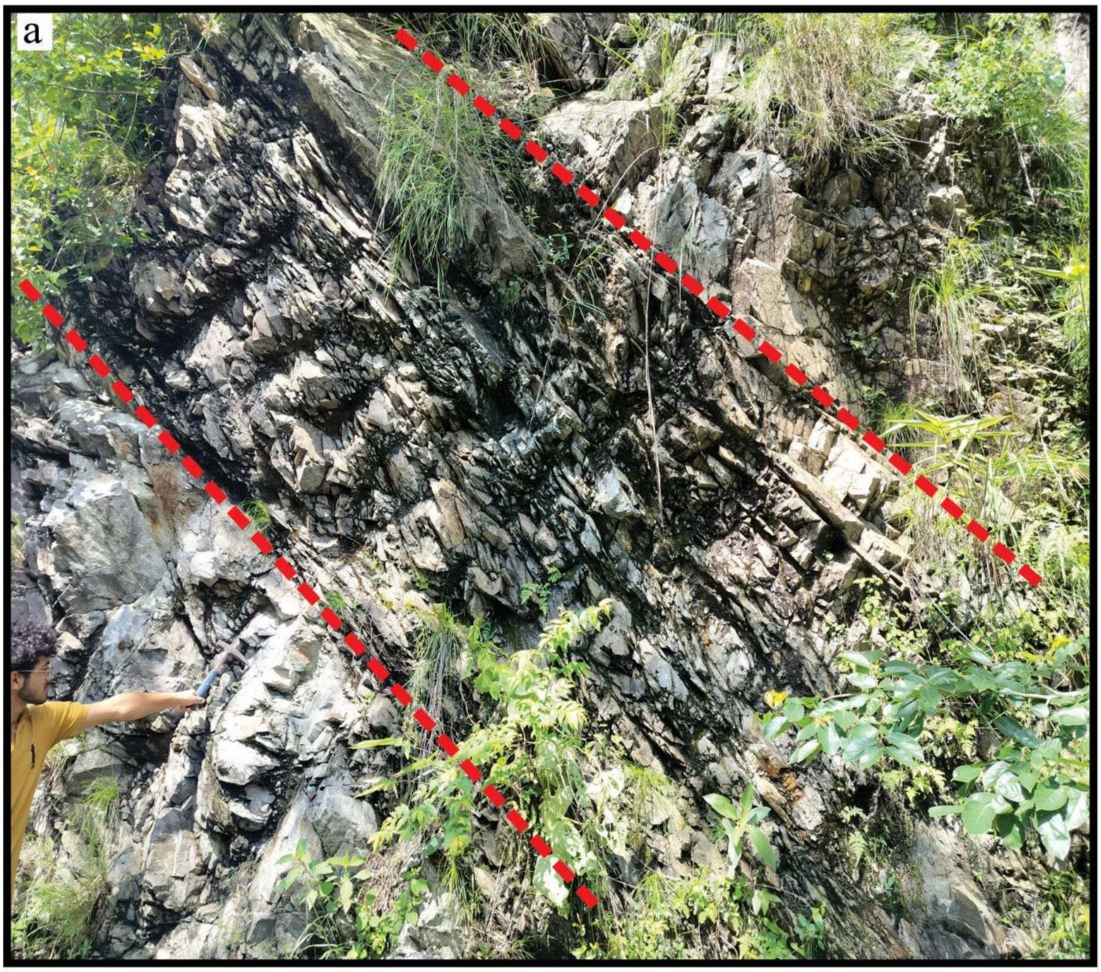
7.6.2 QUARTZITE

Quartzites in the block appear in multiple variations, primarily belonging to the Bhimtal-Bhowali and Nagthat formations.

- **Massive White/Pink Quartzite**: This is the dominant variety, often hard, compact, and massive. In the field, it ranges from milky white to pinkish-purple, particularly near contact zones. It is frequently brecciated and fractured, with fracture planes often hosting secondary mineralization.
- **Ferruginous Quartzite**: As noted in field samples (e.g., ABL/PET/05), this variety is reddish-grey, fine-to-medium grained, and exhibits granular texture. It is characterized

by significant iron oxidation, often observed as reddish ferruginous patches and stains on weathered surfaces.

- **Greenish/Cherty Quartzite**: Often found intercalated with volcanic units, this variety is very fine-grained (cherty) and occasionally exhibits a greenish hue due to the presence of chlorite and epidote, indicating hydrothermal alteration or contact metamorphism.
- **Brecciated Quartzite**: In thrust zones (e.g., near the MBT), the quartzite is highly brecciated, showing angular clasts of quartz cemented by a siliceous or ferruginous matrix.



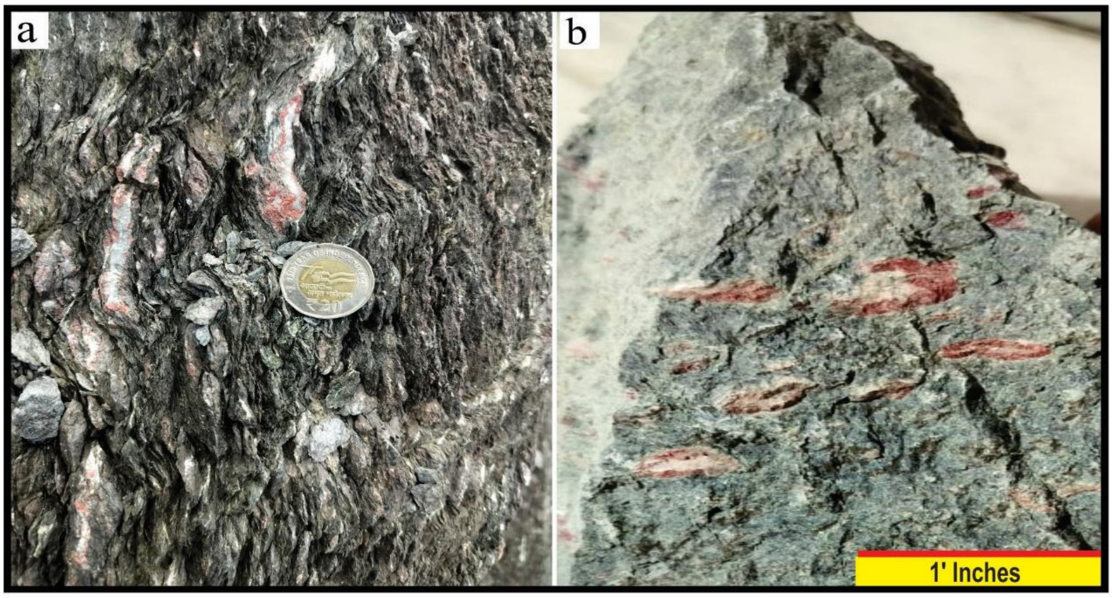
Photograph 7.3 : a). White Quartzite, becoming flaky and platy at the Brittle-Ductile Zone in contact with the Amphibolites.

Photograph 7.4 : a). & b). Intrusive relation of Bhimtal Volcanics (Meta-Basalts) and Bhowali Quartzite (Pink-Quartzite), altered with Epidote.

7.6.3 BASIC VOLCANICS / AMPHIBOLITES (Bhimtal Volcanics)

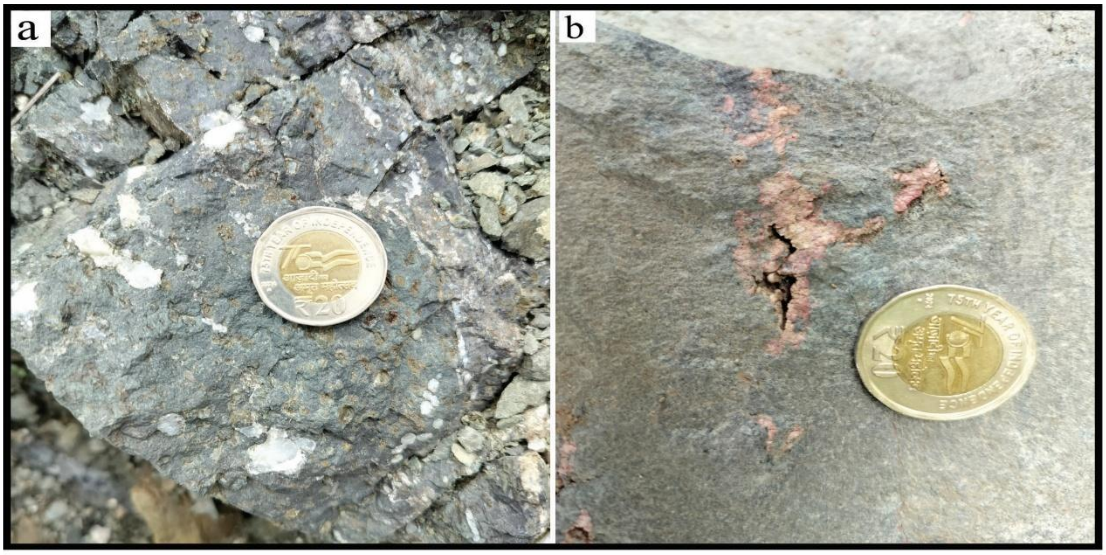
The mafic rocks in the area are part of the Bhimtal Volcanics and have undergone varying degrees of metamorphism, often described as "Trap" or "Basic Rock".

- **Meta-Basalt / Amphibolite:** These rocks are generally greenish-grey, fine-to-medium grained, and altered. In the field, they appear massive to moderately foliated. Petrographic analysis (Sample ABL/PET/07) identifies them as Altered Mafic Rocks (Amphibolite), composed of actinolite-tremolite and chlorite aggregates with relict plagioclase undergoing intense saussuritization.



Photograph 7.5: a). Chlorite schist outcrop showing dark green foliation with calcite-filled kaolinized feldspar. b) Hand specimen of chlorite schist with kaolinized feldspar rimming on calcite-fillings; note weak foliation and alteration halos. (₹20 coin for scale).

- **Chlorite Schist:** In zones of intense shearing and deformation, the massive volcanics grade into highly foliated chlorite schists. These units are soft, green, and fissile, often containing quartz veins and secondary epidote-quartz intrusions.
- **Vesicular/Amygdaloidal Basalt:** Relict vesicular textures are occasionally preserved, with amygdules filled by secondary minerals like quartz, calcite, and epidote, indicating the extrusive nature of the original flows.



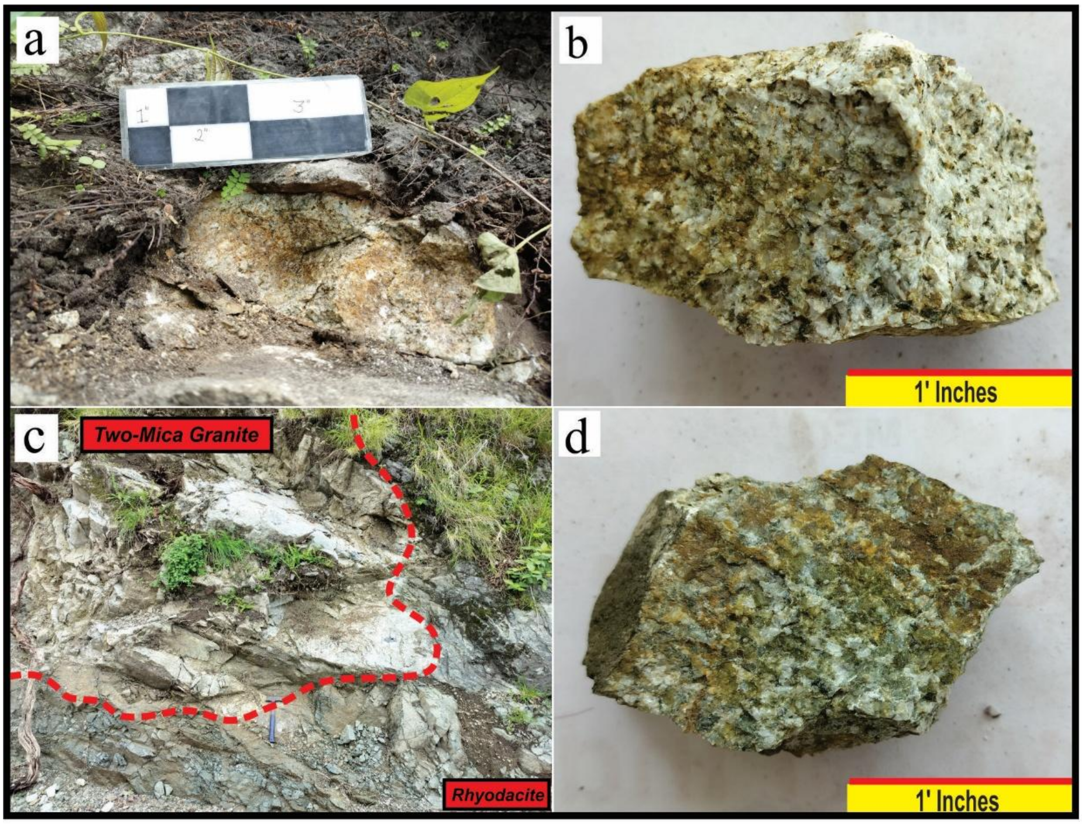
Photograph 7.6: a). Dark grey, fine-grained mafic Meta-Basalts (vesicular basalt) with amygdules filling of sub-rounded to elongated quartz. b). K-feldspar-filled vesicles/amygdules in metabasalt, Salari Thrust area; note pink alteration along margins (₹20 coin for scale).

7.6.4 AMRITPUR GRANITE

The granitic body is intrusive into the quartzite-volcanic sequence and shows significant textural variation.

- **Biotite/Phlogopite Granite:** This is the most common granitic type, appearing as a coarse-to-medium grained, greyish-white rock. It exhibits a hypidiomorphic granular texture. Mineralogically, it is composed of microcline, orthoclase (often perthitic), and quartz, with biotite and phlogopite as the dominant mafic minerals (Samples ABL/PET/26, ABL/PET/27). Field outcrops often show weathering of feldspars to sericite and kaolin.

- **Two-Mica Granite:** Variations include Biotite and Muscovite/sericite micas. This unit displays a intermixed contact with rhyodacite and at places observed with intense shearing and powdered nature. The rock is not mappable, as the litho-units is mixing with the rhyodacite in the area.

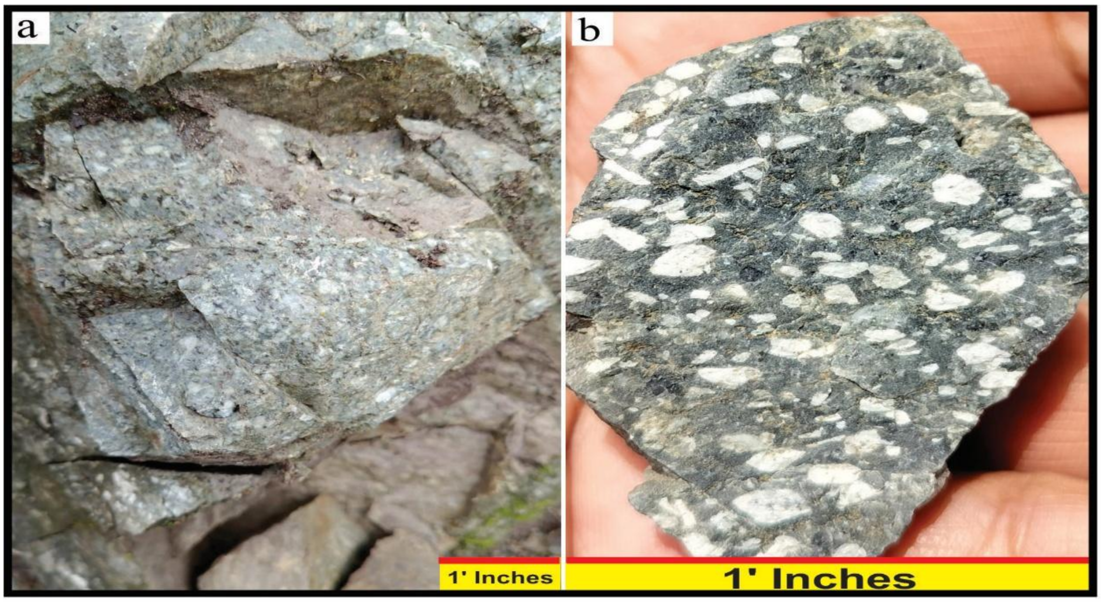


Photograph 7.7: Felsic Intrusive near Salari Thrust & MBT. a) Two-mica granite (phlogopite/biotite-bearing), (3' inches grid for scale). b) Two-mica granite hand specimen (inset, 1' inches scale). c) Intrusive relation between two-mica granite and rhyodacite (Scale: Hammer). d) Rhyodacite intermixed with two-mica granite fragments (inset, 1' inches scale).

7.6.5 RHYODACITE

Often spatially associated with the granites and volcanics, this rock type is distinct in its texture.

- **Porphyritic Rhyodacite:** In hand specimens, this rock is very fine-grained and greyish, showing a clear porphyritic texture (Sample ABL/PET/01, ABL/PET/18). It contains medium-sized phenocrysts of plagioclase (often sericitized) and quartz set in a very fine quartzo-feldspathic groundmass. Field identification can sometimes confuse this with fine-grained granite or massive volcanics, but the porphyritic texture is diagnostic.



Photograph 7.8: a) Rhyodacite outcrop showing aphanitic texture with quartz/feldspar phenocrysts; (inset: 1 inch scale). b) Hand specimen of porphyritic rhyodacite; (inset: 1 inch scale).

7.6.6 SHALE / PHYLLITE

Sedimentary units often intercalated with quartzites or volcanics.

- **Ferruginous Shale/Slate:** These are reddish-grey to purple, very fine-grained, and fissile rocks (Sample ABL/PET/03). They are composed of fine silt-sized quartz and feldspar clasts in a matrix of sericite, chlorite, and ferruginous matter. They often occur as thin bands or lenses within the Nagthat quartzite sequence.

7.6.7 SANDSTONE AND RELATED FACIES OF THE SIWALIKS

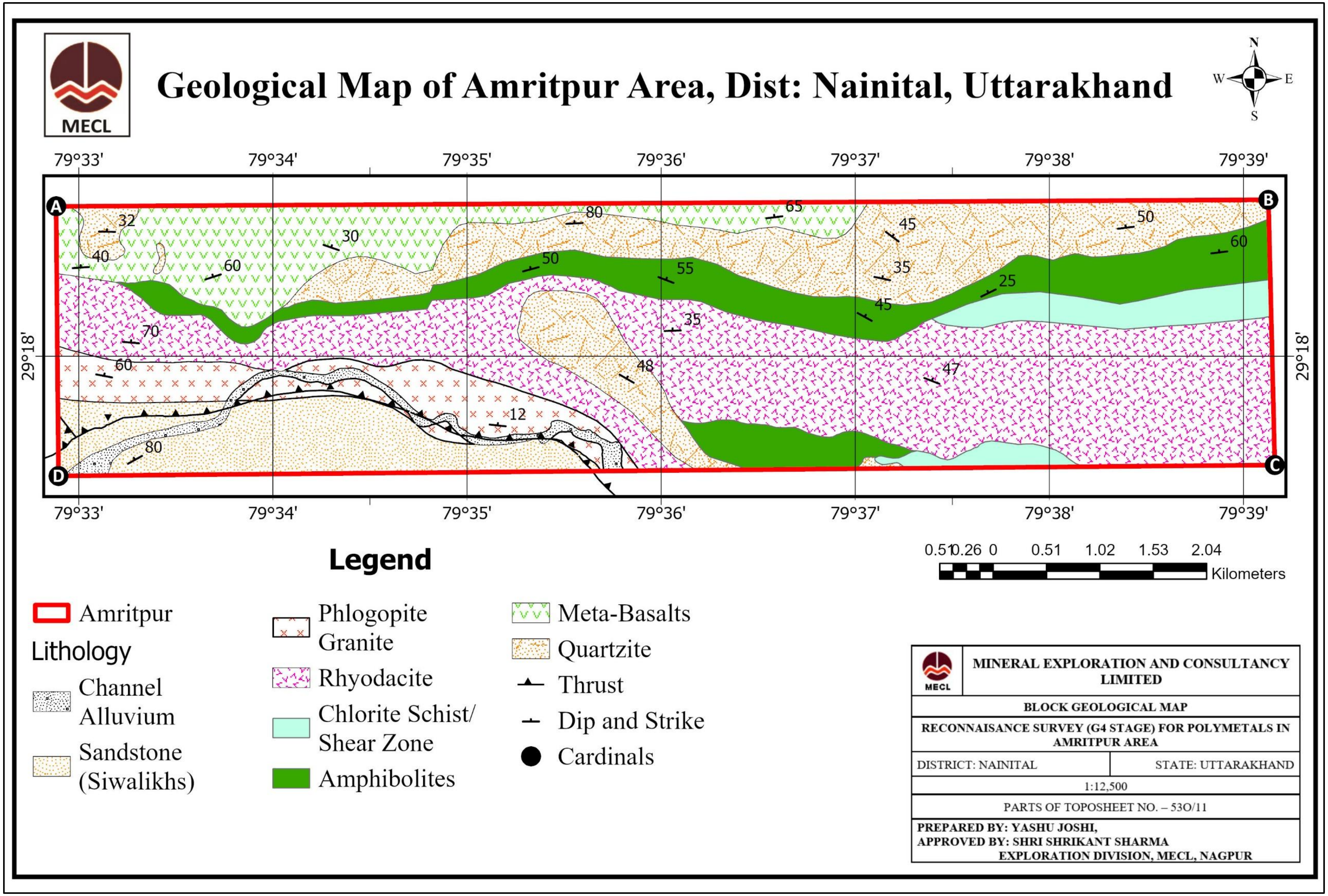
The southwestern part of the Amritpur Block is occupied by Siwalik clastics forming the frontal part of the Lesser Himalayan succession. These rocks occur in erosional and tectonic contact with the underlying Nagthat Formation and locally with the Amritpur Granite Complex along the southern margin of the block.

Photograph 7.9 : a). Near-vertical Middle Siwalik Group succession along Gaula River section near Bhimtal–Bhowali Road bridge, Ranibagh, Amritpur Village; intercalated thick sandstone and shale/mudstone beds tectonically tilted in MBT footwall damage zone (inset: vehicles for scale).

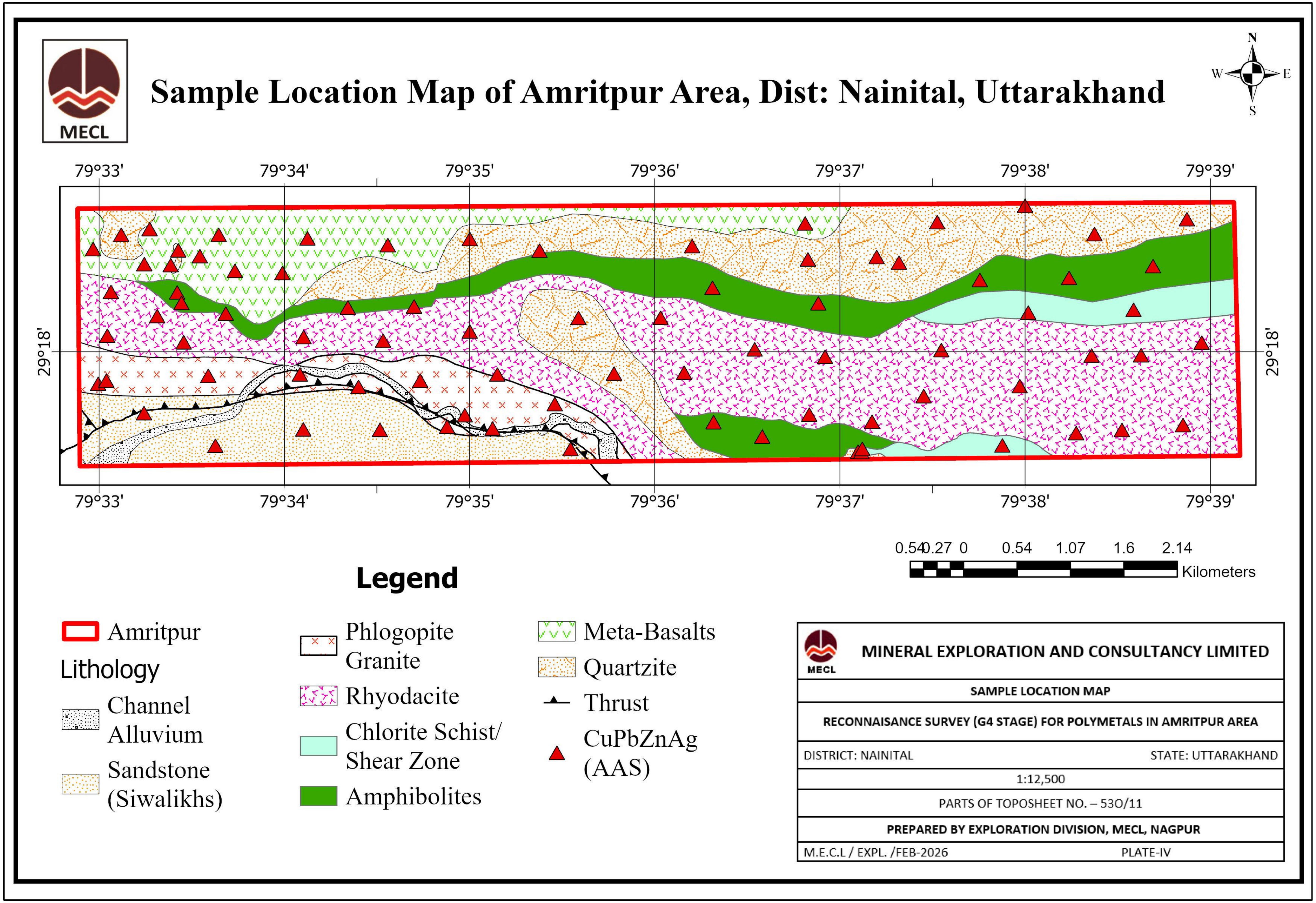
- **Lithology and texture:** The Siwalik succession is dominated by medium- to coarse-grained, light brown to grey sandstone, interbedded with siltstone, claystone and subordinate pebble–cobble conglomerate, consistent with the regional Lower to middle Siwalik assemblage. The sandstones are typically sub-arkosic to lithic arenites in hand specimen, moderately to well sorted, and show planar and trough cross-bedding, ripple lamination and occasional graded bedding, reflecting fluvial channel and overbank depositional settings.

- **Field characteristics:** In the mapped area, Siwalik sandstones form low to moderate relief ridges with blocky to slabby weathering. Individual beds are decimetre to metre scale, commonly laterally persistent, with frequent jointing along NW–SE and NE–SW sets. Locally, thin coal laminae/plys have been observed within finer-grained sandstone–mudstone interbeds, indicating swampy floodplain conditions in parts of the succession.

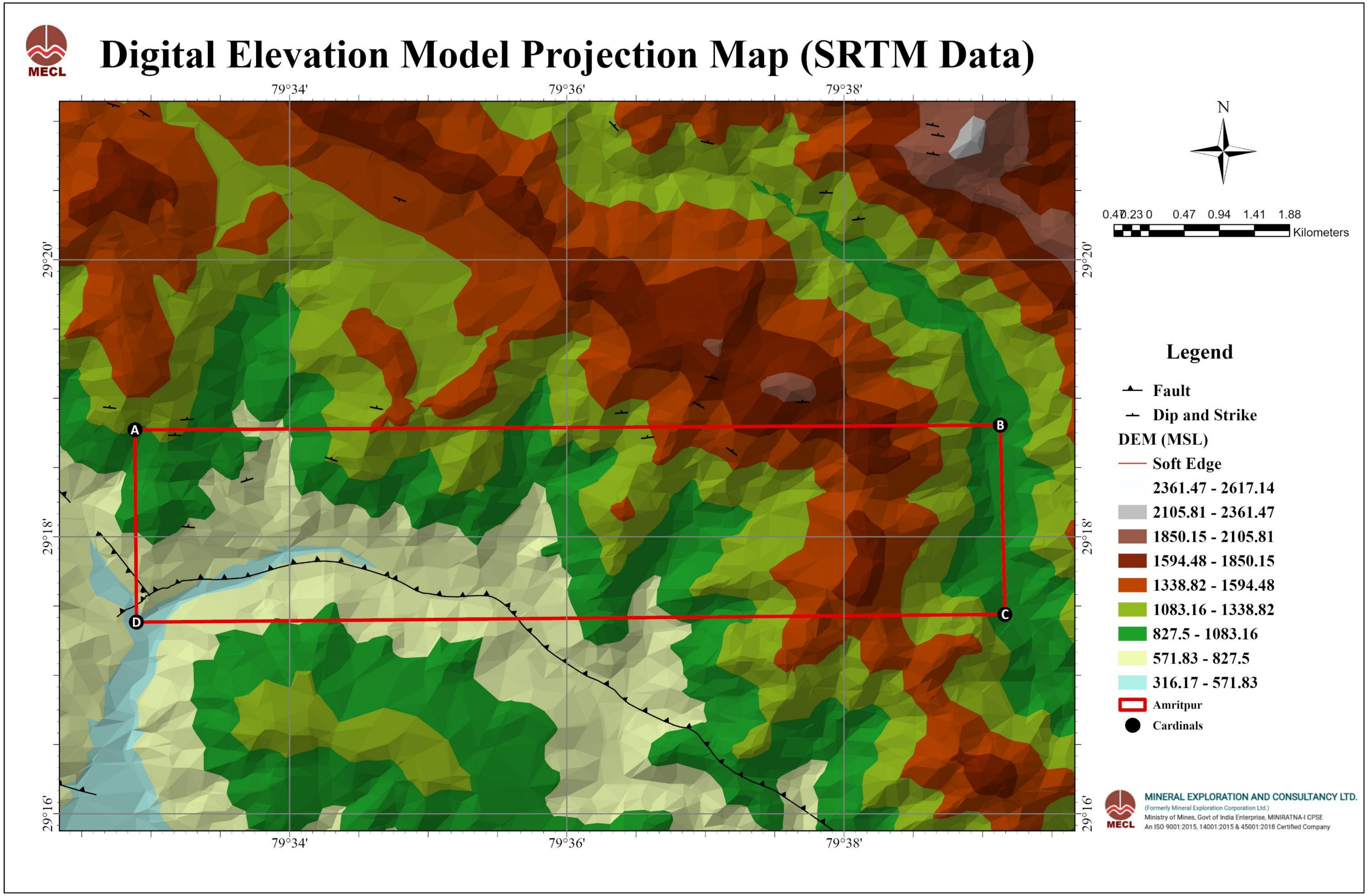
- **Contacts and structural setting:** The contact between Siwalik sandstone and the older Nagthat–Bhimtal–granite assemblage is generally sharp and locally fault-controlled, as noted near the "Sandstone Shivaliks – coal" and "Contact Sandstone Shivaliks and Phlogopite Granite" jolted in the field-notes. Here, steeply dipping Siwalik beds (~60–50°) onlap against or are juxtaposed along faults against gently to moderately dipping Lesser Himalayan quartzites and granites, consistent with foreland basin sediments being tectonically telescoped against the uplifted hinterland.



Text Figure 7.3: Block Geological Map at 1:12,500



Text figure 7.4: Sample locations Map of Amritpur Area, Distt. -Nainital, Uttarakhand.



Text figure 7.5: Digital Elevation Map (DEM) with Sample locations of Amritpur Area, Distt. -Nainital, Uttarakhand

7.7.0 PETROGRAPHIC STUDIES

7.7.1 Petrographic studies were carried out on selected representative rock samples collected from different litho-units of the Amritpur Block in order to understand the mineralogical composition, textural characteristics, alteration features, and metamorphic overprints associated with the regional geological framework. Thin sections were examined under transmitted light using plane- and crossed-polarized conditions. The petrographic observations are summarized below based on lithological grouping and dominant textural features. The photomicrographs are given from Pmg-1 to Pmg-6 and the sample wise details are given as Annexure-VII.

7.7.2 ***Acid to Intermediate Volcanic Rocks (Rhyodacite):*** Rhyodacitic samples are very fine grained and exhibit a porphyritic texture, comprising phenocrysts of plagioclase, orthoclase/microcline, and quartz set in a very fine quartz–feldspathic groundmass. Plagioclase phenocrysts are extensively sericitized, while feldspars locally show kaolinization. Chlorite, biotite, epidote, and sericite occur as alteration products, forming patchy aggregates and pseudomorphic replacements. Accessory phases include apatite, monazite (locally rimmed by suspected allanite), and opaques, while ferruginous matter occurs as disseminations and fillings. These features indicate intense hydrothermal alteration superimposed on primary igneous textures. (Photomicrograph, Pmg-5).

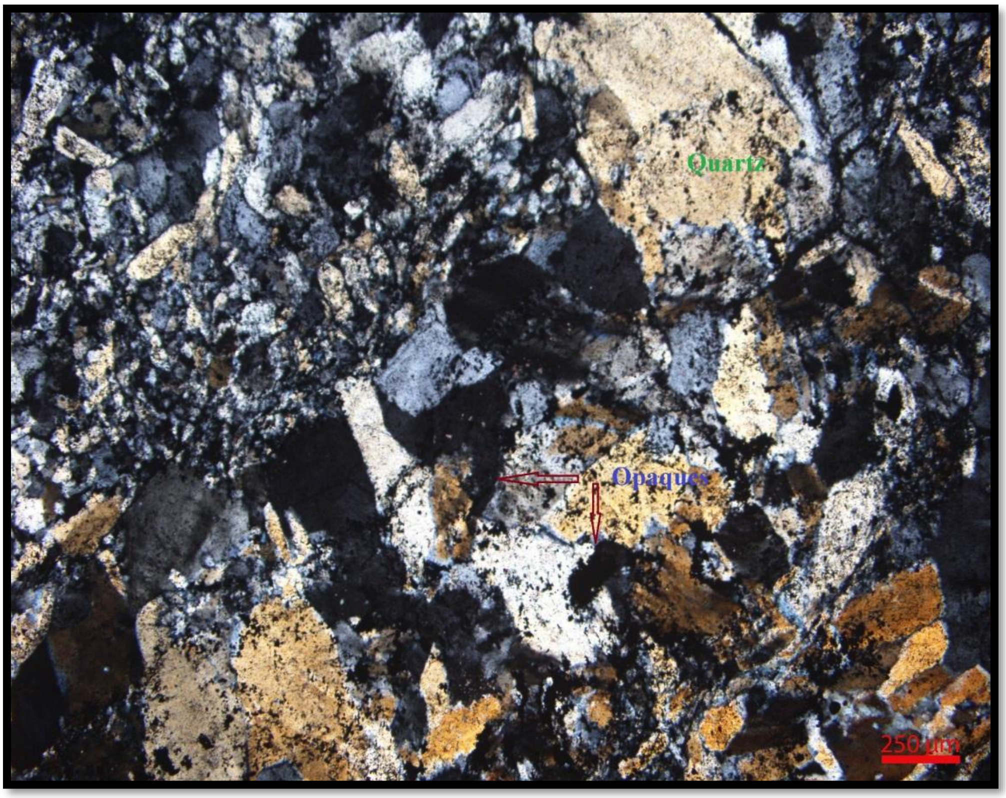
7.7.3 ***Sedimentary and Metasedimentary Rocks:*** Ferruginous shale samples consist of very fine quartz and feldspar clasts within a clay-rich matrix, showing thin sub-parallel lamination defined by biotite–chlorite–sericite aggregates. Kaolinised feldspar clasts, ferruginous staining, and disseminated opaques are common, with accessory tourmaline occurring as fine prismatic grains. Ferruginous quartz arenite and quartzite samples are dominated by subrounded to subangular quartz grains with compact grain contacts and minor clayey matrix. Opaques occur as disseminated grains associated with ferruginous staining. Microfractures and granulation textures locally indicate brittle deformation and fluid-assisted recrystallisation. (Photomicrograph, Pmg-1 & 2).

7.7.4 ***Mafic and Metamorphic Rocks (Amphibolite / Altered Mafics):*** Altered mafic rocks and amphibolites are characterized by actinolite–tremolite, chlorite, epidote, saussuritised plagioclase, quartz, and opaques. Amphibole minerals occur both as fine flaky aggregates and as pseudomorphic prismatic crystals. Plagioclase shows intense saussuritisation and sericitisation, while epidote commonly develops as fine granular aggregates. Carbonates and ferruginous matter occur as late-stage fillings, suggesting multi-phase alteration involving propylitic to carbonate overprints (Photomicrograph, Pmg-3 & 4).

7.7.5 ***Granitic Rocks (Amritpur Granite):*** Granite samples exhibit coarse- to medium-grained hypidiomorphic granular texture, composed of microcline/orthoclase with perthitic exsolutions, quartz with undulose extinction, and plagioclase showing moderate sericitisation. Mafic minerals include phlogopite/biotite, commonly altered to chlorite. Epidote, sphene, and opaques occur as accessory phases, while ferruginous fillings are locally developed. These features reflect post-emplacement deformation, hydrothermal alteration, and metamorphic re-equilibration of the granite (Photomicrograph, Pmg-6).

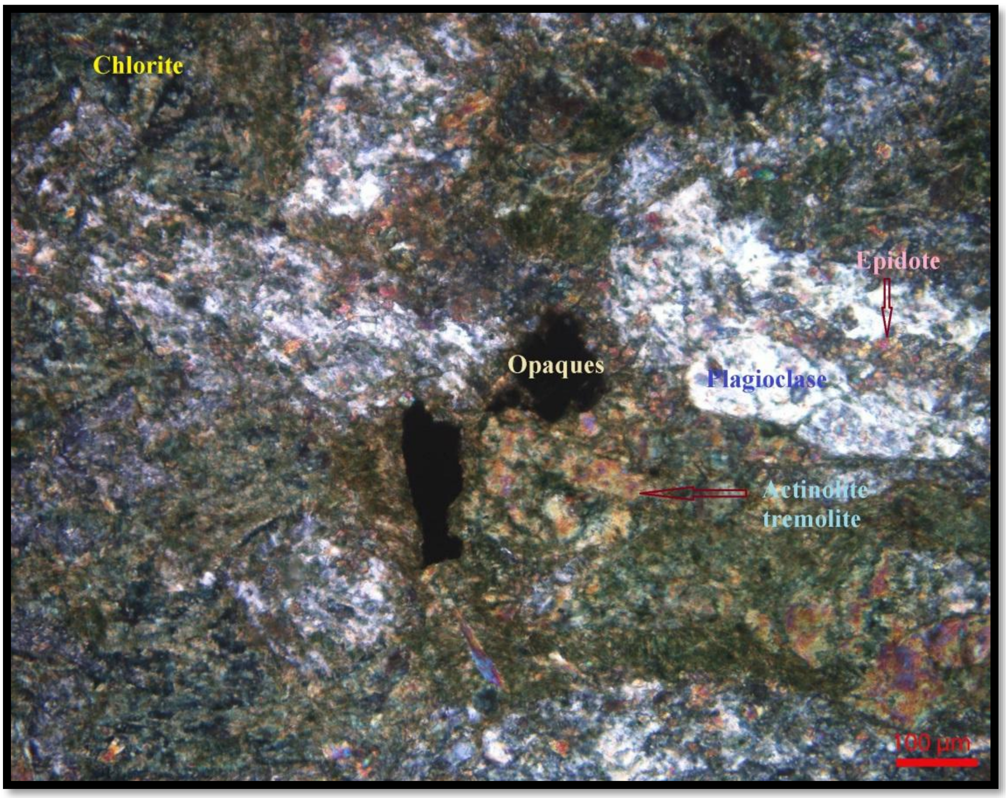
Pmg – 1: Photomicrograph showing subrounded to subangular clasts of quartz floating over clayey matrix with associated disseminated opaques in ferruginous quartz arenite as seen under crossed nicols.

Specimen No.: ABL/PET/4 **Magnification: 40X**



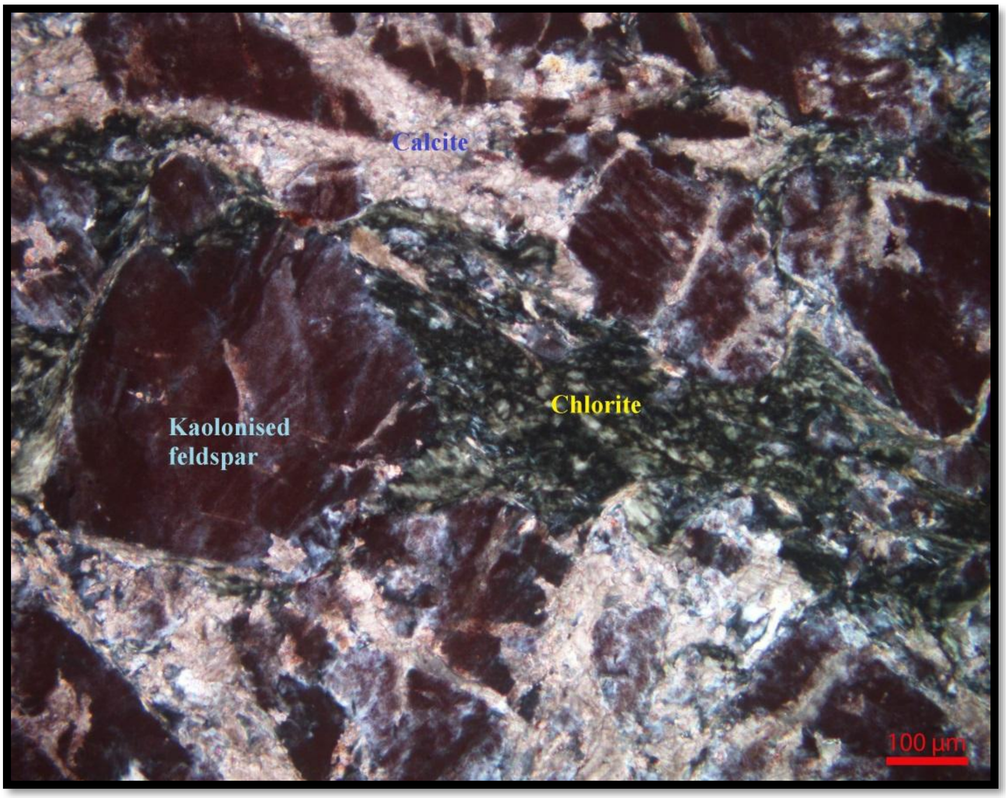
Pmg – 2: Photomicrograph showing fine to medium subhedral to anhedral quartz with compact contacts and associated opaque dissemination in ferruginous quartzite as seen under crossed nicols.

Specimen No.: ABL/PET/5 **Magnification: 40X**



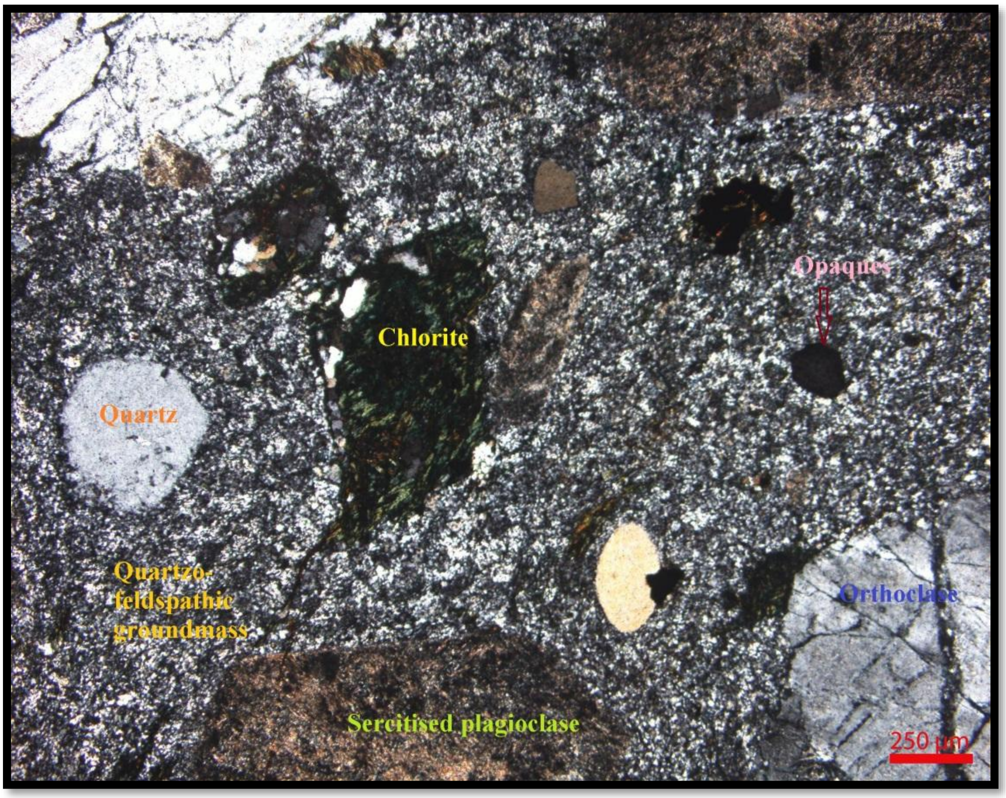
Pmg – 3: Photomicrograph showing association of actinolite-tremolite, saussuritised plagioclase, chlorite and opaques in amphibolite as seen under crossed nicols.

Specimen No.: ABL/PET/7 **Magnification: 100X**



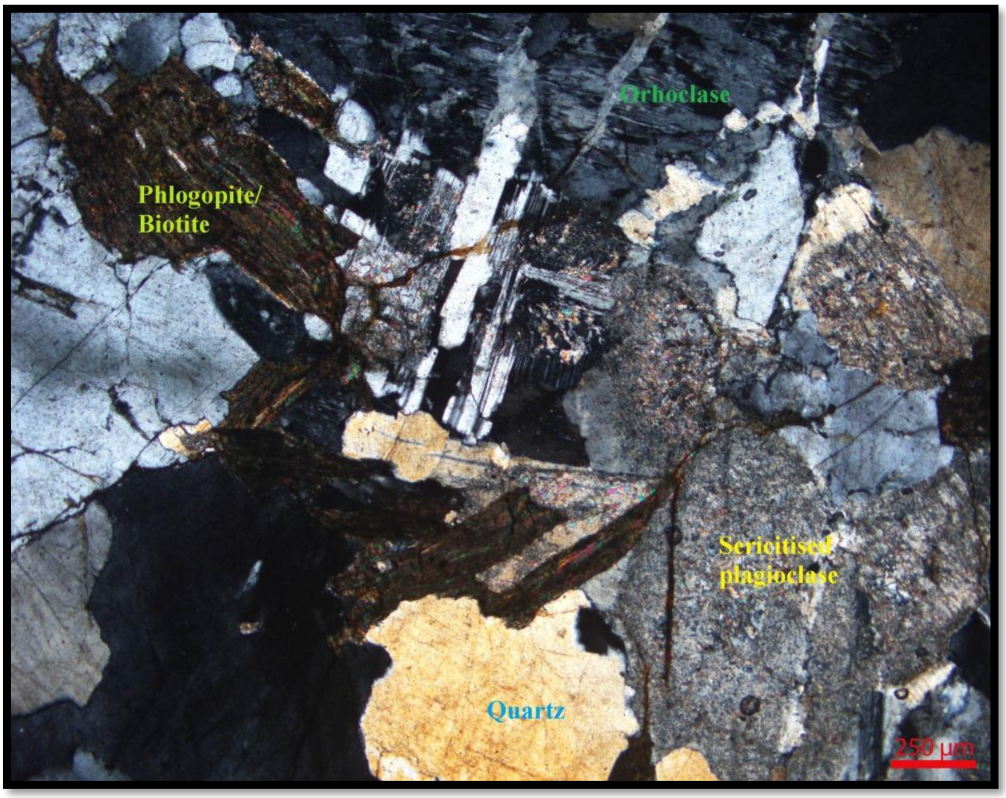
Pmg – 4: Photomicrograph showing kaolinised feldspar is being cut across by calcite and chlorite veins as seen under crossed nicols.

Specimen No.: ABL/PET/17 **Magnification: 100X**



Pmg – 5: Photomicrograph showing phenocrysts of sericitised plagioclase, orthoclase and quartz set in a very fine quartz-feldspathic groundmass and associated chlorite patches and opaques in rhyodacite as seen under crossed nicols.

Specimen No.: ABL/PET/18 **Magnification: 40X**



Pmg – 6: Photomicrograph showing association of orthoclase with perthitic exsolutions, quartz, sericitised plagioclase and phlogopite/ biotite in granite as seen under crossed nicols.

Specimen No.: ABL/PET/26 **Magnification: 40X**

7.8.0 MINERAGRAPHIC STUDIES

7.8.1 Mineragraphic studies were conducted on polished sections prepared from selected mineralised samples to identify ore mineral assemblages, textural relationships, paragenesis, and alteration features. Examination was carried out under reflected light microscopy, and the results are summarized below. The photomicrographs are given from Pmg-7 to Pmg-10 and the sample wise details are given as Annexure-VIII.

7.8.2 ***Pyrite,*** occurring as **coarse to medium intrusive patches, veins, and veinlets**, locally constituting up to ~100% of the ore assemblage. Pyrite is frequently associated with **hematite, goethite, limonite, and rutile/anatase**, reflecting varying degrees of oxidation and supergene alteration (Photomicrograph, Pmg-7 & 10).

7.8.3 ***Chalcopyrite,*** occurs mainly as **very fine disseminated specks, inclusions, or fracture fillings**, commonly associated with pyrite and sphene. In several samples, chalcopyrite is rimmed or partially replaced by **covellite and digenite**, indicating secondary copper enrichment (Photomicrograph, Pmg-9 & Pmg-10).

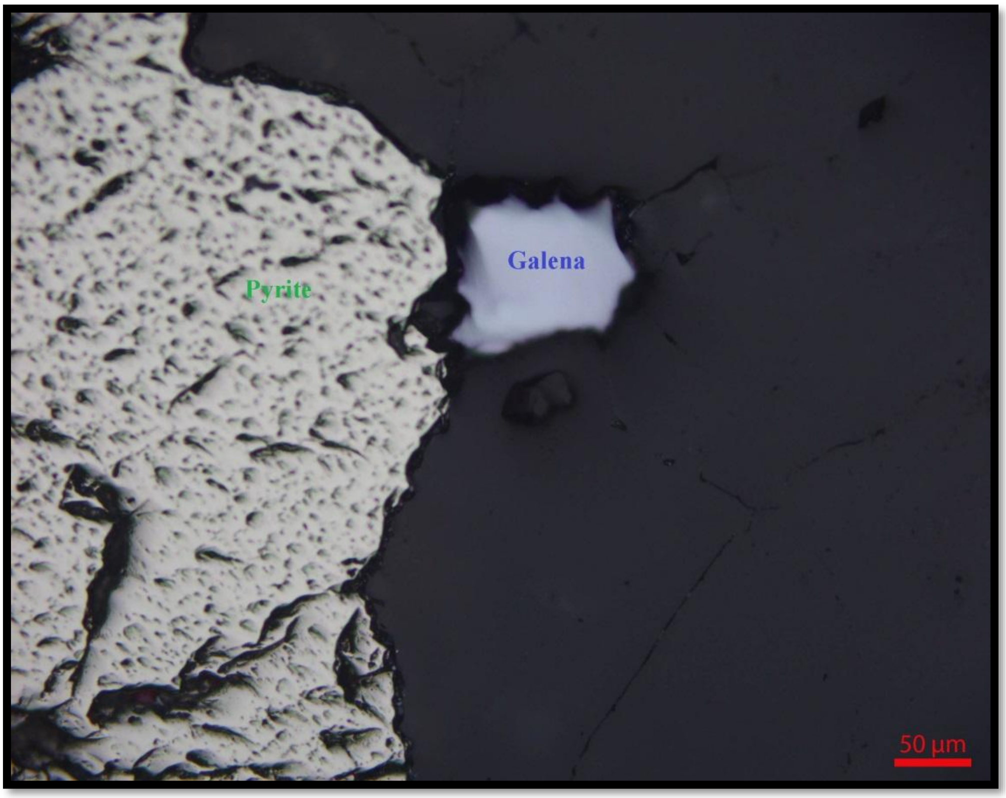
7.8.4 ***Hematite and ilmenite,*** occur as disseminated grains, bladed aggregates, and dendritic veinlets, with ilmenite locally showing relict textures within sphene (Photomicrograph, Pmg-8).

7.8.5 ***Sphene***, is observed as anhedral patches and veinlets, often replacing ilmenite and hosting very fine chalcopyrite inclusions.

7.8.6 ***Galena And Pyrrhotite,*** as minor sulphide phases, occurring as trace disseminations or inclusions within pyrite and gangue minerals. Supergene products such as goethite and limonite are developed as patchy fillings and reddish amorphous aggregates, indicating near-surface oxidation (Photomicrograph, Pmg-7 & 10).

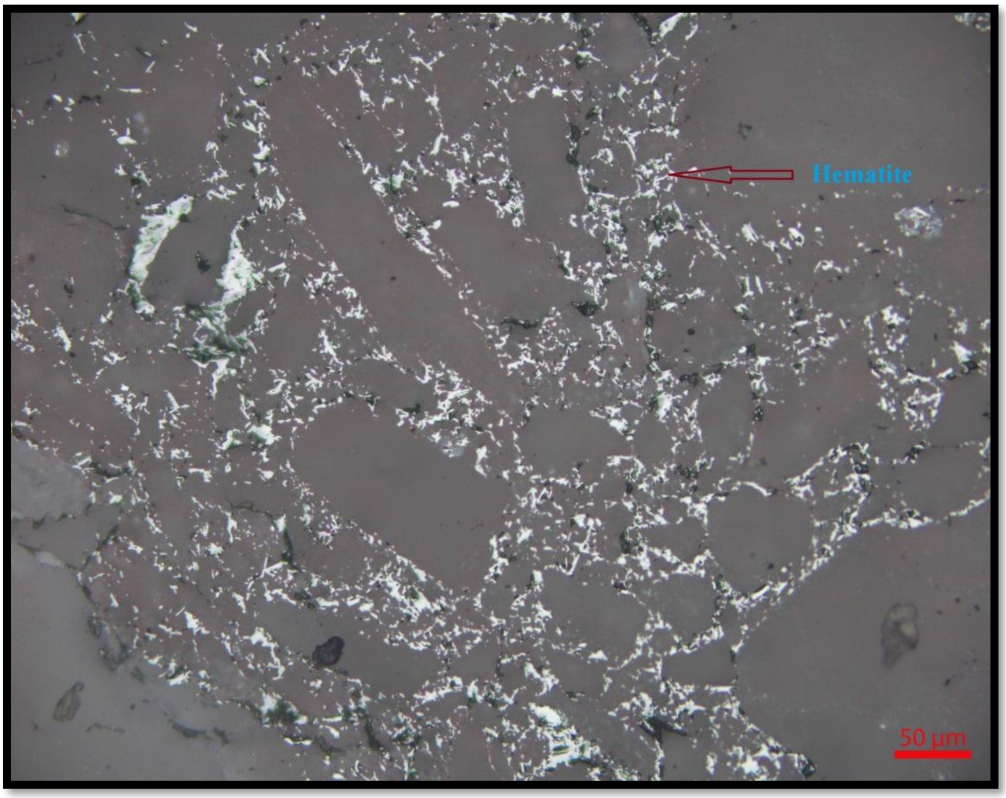
7.8.7 ***Paragenetic Implications:*** The mineragraphic observations suggest a primary sulphide assemblage dominated by pyrite with subordinate chalcopyrite, followed by oxidation and supergene alteration resulting in hematite, goethite, covellite, and digenite. The association of sulphides with sphene–ilmenite assemblages and altered mafic rocks indicates a hydrothermal mineralisation system, structurally controlled and overprinted by later deformation and weathering processes.

7.8.8 ***Conclusion:*** Petrographic and mineragraphic studies collectively indicate that the Amritpur Block hosts polyphase lithological assemblages affected by intense deformation, hydrothermal alteration, and sulphide mineralisation, dominated by pyrite with subordinate Cu-bearing sulphides. These observations provide important constraints on alteration styles, mineral paragenesis, and structural controls, forming a robust basis for reconnaissance-stage evaluation of polymetallic mineral potential.



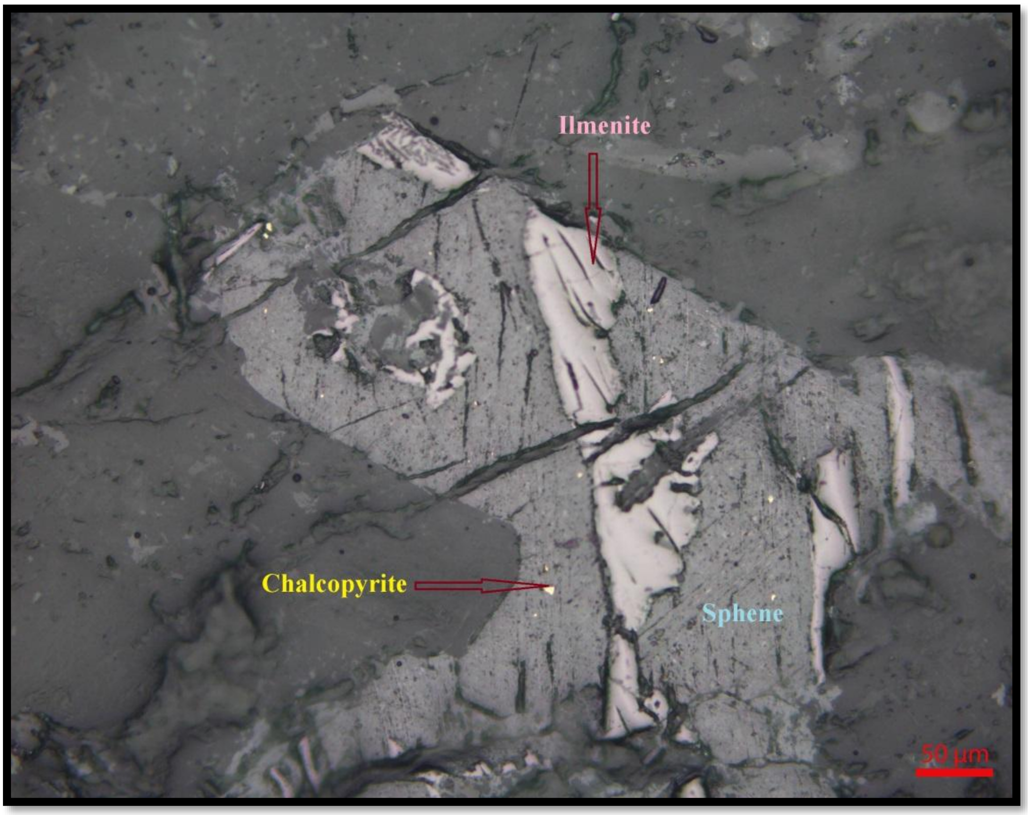
Pmg – 7: Photomicrograph showing presence of galena grain in association with pyrite patch as seen under reflected light.

Specimen No.: MBL/MG/ 01 **Magnification: 200X**



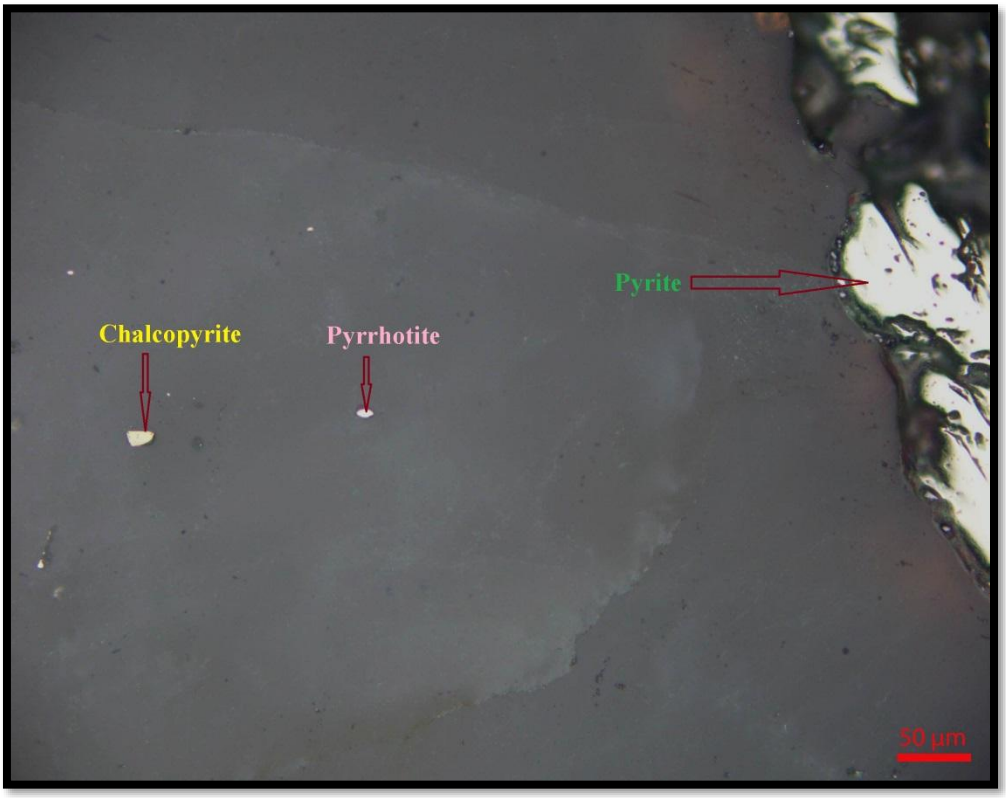
Pmg – 8: Photomicrograph showing very thin veins/ veinlets of hematite as seen under reflected light.

Specimen No.: MBL/MG/ 02 **Magnification: 200X**



Pmg – 9: Photomicrograph showing relicts of ilmenite with sphene and very fine inclusions of chalcopyrite within sphene as seen under reflected light.

Specimen No.: MBL/MG/ 03 **Magnification: 200X**



Pmg – 10: Photomicrograph showing presence of very fine chalcopyrite and pyrrhotite specks and pyrite patches as seen under reflected light.

Specimen No.: MBSM-10 **Magnification: 200X**

7.9.0 STRUCTURES

7.9.1 The bedding attitudes in the Lesser Himalayan quartzites and associated units are highly variable due to intense folding and faulting. In the Quartzite, bedding commonly strikes NW–SE with dips from 40° to near-vertical towards NE or SW; S-folds and tight folds are observed with bedding bearing around N308, indicating a regional NW–SE compression direction. Near major contacts (Granite–Meta-Basalts, Quartzite–Mudstone, Quartzite–Meta-basalt), bedding becomes highly disturbed or destroyed, with lensoidal and pinching relations, reflecting strong strain partitioning along these boundaries.

7.9.2 In the Siwalik Sandstone, bedding is gentler, generally 20–40°, with strikes between N290 and N320, locally recorded as sandstone joints and bed attitudes at "Sandstone – joints N290–N220". But the beddings are also observed near to steep dips around ~60°, on the open section of Bhimtal-Bhowali road.

7.9.3 Folding is pervasive and affects both quartzites and mafic volcanics.

- **S-folds in Quartzite:** At several localities (e.g., Quartzite with S-fold and chlorite along bedding), open to tight S-shaped folds trend approximately E–W, with fold hinges oriented around N308. These folds are associated with chlorite concentration along bedding, indicating flexural slip and low-grade metamorphic overprint.

- **Anticlinal/Synclinal Patterns:** Opposite dips in adjacent quartzite panels (white vs. pink quartzite) and changing dip directions suggest local syncline–anticline pairs developed in response to thrust stacking, especially near the Salari Thrust zone.

- **Folded Veins:** Quartz–hematite/jasper veins in cherty quartzite show crooked, zig-zag geometries and pinch–swell structures, indicating folding of fracture-controlled veins during continued deformation.

7.9.4 FAULT, THRUST AND SHEAR ZONES

- **Main Boundary Thrust (MBT):** The MBT constitutes the dominant thrust structure with strain-partitioned transpression accommodating deformation in the damage zone. The fault surface dips northward at angles typically between 20-40° and exhibits evidence of recent movement in the Quaternary.
- **Salari Thrust:** This is a major NE-dipping thrust that juxtaposes Bhimtal metabasalts and Nagthat quartzites against Amritpur Granite and, locally, Siwalik clastics.

Proximity to the thrust zone, the Meta-basalts are crushed and powdered, with intense shearing, mylonitization and pulverization of other adjacent rocks. The Salari Thrust shows evidence of both Miocene ductile deformation and Quaternary brittle reactivation.

- **Local Faults and Shear Zones:** In the central and northern parts, chlorite schist and amphibolite schist record rhombic thrust fabrics, slaty–schistose foliation, and sheared quartz veins; dip-data such as 62°N/191° (fracture plane) and slickenside lineation 50°/231° indicate oblique slip along these thrust planes. These subordinate structures record late-stage strike-slip motion with components of normal faulting, accommodating along-strike variation in shortening and uplift.

- **Contact Faults:** Multiple local faults coincide with lithological contacts, e.g., (i) Basalt/Meta-basalt overlain by quartzite with contact data 32°N/130°, strike N220 at the Salari Thrust; (ii) faults and cleavages in meta-basalts near salari area, within the thrust zone; and (iii) faulted contacts between Siwalik sandstone and Amritpur Granite.

- **Quartz Vein Shears:** Criss-cross quartz vein networks with pinch-and-swell geometry, ductile stretching of veins, and K-feldspar–quartz veins along chlorite-schist foliation planes are common, acting as conduits for sulphide and iron-oxide mineralization (e.g., magnetite, pyrite, malachite, azurite).

- **Joints, Shear Zones and Mylonites :** Joint Sets in Granite: Amritpur Granites show systematic joint sets trending approximately N310 and N285 (and locally N345 and N255), with steep dips, indicating a brittle response during late uplift and exhumation.

7.9.5 DAMAGE ZONE STRUCTURE AND DEFORMATION PATTERNS

The MBT damage zone in the Amritpur area displays a complex imbricate structure with distinct litho-tectonic domains, such as:

- **Quartzite Mega-pod:** This competent unit shows brittle deformation characteristics typical of quartzite in thrust zones.
- **Amphibolite:** This unit represents metamorphic rocks incorporated into the imbricate structure, showing evidence of both ductile and brittle deformation.

7.9.6 GEODYNAMICS AND HIMALAYAN TECTONICS

India-Asia Collision and Orogenic Evolution

7.9.6.1 The geological architecture of the Amritpur region reflects geodynamic processes during continental collision that began during the Paleocene-Eocene, approximately 58-60 million years ago. The kinematic evolution in the Kumaun region is characterized by three distinct phases reflecting progressive incorporation of Indian plate lithosphere into the orogenic wedge:

7.9.6.2 **Paleocene-Eocene Collisional Phase (58-50 Ma):** Initial collision between the Indian and Eurasian plates resulted in emplacement of the Tethyan Himalayan Sequence and initiation of crustal thickening.

7.9.6.3 **Late Oligocene-Miocene Phase (25-10 Ma):** Transportation of Higher Himalayan Crystalline over Lesser Himalaya along the Main Central Thrust (MCT) occurred during this interval, with progressive propagation of thrust tectonics toward the foreland.

7.9.6.4 **Middle Miocene-Quaternary Phase (15 Ma-Present):** Development of the Lesser Himalayan Duplex and propagation of thrust tectonics toward the foreland characterized this phase. In the Amritpur area, dominant MBT activity occurred from approximately 14-13 Ma, with documented exhumation of the Amritpur Granite as tectonic slivers, followed by lower-magnitude reactivation around 5 Ma.

7.9.7 Exhumation Mechanisms

7.9.7.1 The exhumation of the Amritpur Granite during the middle Miocene resulted from tectonic denudation driven by movement along the MBT. The thermochronological data indicate exhumation from depths of 8-10 kilometres over approximately 1-2 million years, implying exhumation rates of approximately 1-2 mm/year. This rapid exhumation reflects the high strain rates and crustal uplift rates characteristic of the Himalayan orogen during the middle Miocene, when significant portions of the Indian lower crust were underthrust and then exhumed along major thrust zones. The transition to slower exhumation and eventual quiescence of the MBT by the Quaternary suggests a progressive shift in deformation toward the foreland with development of newer thrust structures.

7.10.0 MINERALISATION

7.10.1 Mineralization in the Amritpur Block has been delineated on the basis of Cu–Pb–Zn–Ag assays, multi-element geochemistry, petrography/mineragraphy and detailed field observations.

7.10.2 The mineralization identified so far is polymetallic, with copper as the principal metal, accompanied by subordinate lead, zinc and silver. The metal distribution is heterogeneous, with a broad background to moderately anomalous halo overprinted by a limited number of strongly enriched Cu and Pb–Ag localities. Mineralization is closely associated with Bhimtal metabasalts/amphibolites, chlorite–amphibole schists, quartzites of the Nagthat Formation and contact zones involving Amritpur Granites and rhyodacitic rocks, and is strongly controlled by thrusts, shear zones and fracture–vein systems.

7.10.3 Within the mapped area, visible mineralization is confined to specific structural and lithological settings, rather than being uniformly developed across any single unit. Sulphides are observed predominantly as pyrite-rich veins and patches in metabasalts, chlorite–amphibole schists and purple shale–volcanic xenoliths along the Salari Thrust and subsidiary shear zones, with local chalcopyrite visible in hand specimen and under the microscope. Pockets of sulphide mineralization are also recorded at basalt–quartzite contacts and in quartz–hematite/jasper veins within cherty quartzites of the Nagthat Formation, commonly accompanied by strong iron oxidation.

7.10.4 The vadose zone, being the unsaturated part of the soil above the water table, has access to atmospheric oxygen. When oxygen-rich water infiltrates the vadose zone, it oxidizes iron (Fe^{2+}) in minerals to form iron oxides (Fe^{3+}), thus the limonite and goethite. Thus, oxidations are intensely distributed along the fractures and joint sets. Supergene effects are evident at several localities as malachite and azurite staining along oxidized quartz veins hosted by amphibolite and chlorite–schist shear zones, indicating near-surface remobilization of copper from primary sulphides.

7.10.5 The highest-order indication of mineralization comes from a small number of strongly anomalous samples (e.g., ABL/BR/67, ABL/BR/64 and several Pb–Ag-rich sites), where Cu reaches sub-percent levels and Pb and Ag locally exceed background by one to two orders of magnitude, thereby defining discrete polymetallic centres rather than a diffuse, uniformly mineralized horizon. These anomalies are consistently located within, or immediately adjacent to, Bhimtal metabasalts/amphibolites and chlorite–amphibole schists, at contacts between mafic units and Nagthat quartzites or rhyodacitic–granite bodies, and along major structures such as the Salari Thrust and subsidiary shear zones, confirming a strong structural–lithological control on metal focusing.

7.10.6 Petrographic work shows that these favourable hosts are Fe–Mg-rich, variably altered mafic rocks and their contact variants, characterized by abundant amphibole, chlorite and epidote, locally grading into hornfelsic or silicified facies near granitic intrusions, thus providing reactive and fractured pathways for hydrothermal fluids. Mineragraphy complements this by documenting pyrite-dominated sulphide assemblages, with chalcopyrite (locally rimmed by covellite/digenite), minor galena and subordinate Cu-sulphides, intimately associated with hematite, goethite, ilmenite, rutile/anatase and sphene, particularly in the Cu-anomalous mafic samples. This combination of Fe-oxide–sulphide assemblages, sulphide veining and replacement textures is consistent with hydrothermal introduction and subsequent partial oxidation of base-metal sulphides in structurally prepared mafic and contact zones.

7.10.7 The mineralization indicator noted from the field observations provide direct visual confirmation, such as : (i) pyrite-rich quartz veins (e.g., ABL/BR/042–044) and sulphidic purple shale–volcanic xenoliths are concentrated along the Salari Thrust and associated mylonite zones; (ii) pockets of sulphide mineralization occur at basalt–quartzite contacts (e.g., ABL/BR/120) and within quartz–hematite/jasper veins in cherty Nagthat quartzites; and (iii) malachite and azurite staining is observed along oxidized quartz veins in amphibolite–schist shear zones (e.g., ABLBR066-067, trend N326°), indicating active supergene copper redistribution above primary sulphide shoots. Where geochemical anomalies, these field indicators and the petrographic/mineragraphic signatures coincide, they collectively define zones of indicator mineralization that are structurally controlled, lithologically selective and hydrothermal in origin, and which warrant a further detailed investigation in the area, with drilling, and future G-3-level work.

7.10.8 The mineralization patterns are found consistent with the work on the Bhimtal–Bhowali volcanics and the Amritpur Granite–Ramgarh–Nagthat assemblage, they are consistent with a reworked hydrothermal system with VMS-like affinities that has been structurally dismembered and remobilized within the Lesser Himalayan thrust belt. The present G-4-stage work thus confirms a significant polymetallic potential, warranting further investigation at the identified Cu- and Pb–Ag-anomalous sites through denser geochemical sampling and targeted drilling.

7.10.9 Regionally, polymetallic mineralization is interpreted as hydrothermal, originally linked to Paleoproterozoic volcanic and intrusive activity (Bhimtal Volcanics and Amritpur Granite), and subsequently reworked and focused along Lesser Himalayan thrusts and folds. The coincidence of high-strain zones, major contacts and strong alteration with Cu–Pb–Zn–Ag anomalies support a structurally controlled, orogenic-wedge setting favourable for reworked VMS/SEDEX-style systems.

CHAPTER-8

PREVIOUS WORK

8.1.0 DETAILS OF PREVIOUS EXPLORATION CARRIED OUT BY OTHER AGENCIES

8.1.1 Previous geological investigations in the Amritpur Block and surrounding areas in the Bhimtal–Bhowali–Ranibagh region of Nainital District have focused primarily on stratigraphic mapping, structural analysis and preliminary geochemical appraisal for base metals (Cu–Pb–Zn) and associated precious metals (Ag, Au, PGE). Work spans from the late 19^{th} century British period through GSI efforts up to the 1970s–1980s, with scattered modern studies on tectonics and granite petrogenesis. No large-scale drilling or resource estimation has been undertaken to date, leaving the block at a reconnaissance level with strong potential for polymetallic mineralization as indicated by historical anomalies and structural controls.

8.1.2 Early investigations (Late 19^{th} to Mid-20^{th} Century): The foundational work in the Amritpur–Bhimtal region was conducted by Middlemiss (1880, 1890), who first documented the basic lithological assemblage of granites, microgranites and volcanogenic sequences, noting anomalous superposition of older and younger rock units suggestive of complex tectonics favourable for mineralization. Nautiyal (1943–44) refined the stratigraphic framework by correlating Bhimtal–Bhowali quartzites with the Ramgarh Formation and proposed tectonic transport of granitic blocks, providing early insights into the role of thrusting in metal emplacement.

8.1.3 Base Metal Exploration (1950s–1960s): Regional mapping and preliminary base metal investigations in the 1950s–1960s by Kharakwal (1951), Srivastava (1951) and Pande et al. (1963) identified ancient copper workings in the Amritpur area. Raina and Dungrakoti (1966) reported sulphide mineralization in the nearby Galpakot region, documenting chalcopyrite, pyrite and galena in structural conduits, establishing the polymetallic character of the Lesser Himalayan volcanics and their contacts.

8.1.4 Detailed Geochemical and Structural Studies (1970s–1980s): Jangpangi et al. (1970) conducted preliminary geochemical appraisals confirming Cu–Pb–Zn anomalies across blocks including Kimkhet and Khansyun. Chattopadhyaya and Saran (1968) used hydrogeochemistry to demonstrate syngenetic mineralization linked to basic–ultrabasic rocks. Desai's work on the spillite–keratophyre–soda granite association in

Ranibagh–Amritpur linked magmatic evolution to mineralization. Varadrajan's (1978) K–Ar dating of the Amritpur Granite (~1900 Ma) and Chatterjee's (1979) demonstration of its synkinematic emplacement highlighted the granite's role in creating fluid pathways during deformation.

8.1.5 Recent studies have emphasized tectonics rather than mineral exploration. Shah et al. (2012) described sinistral transpression along the Main Boundary Thrust (MBT) near Amritpur, with a 100 m fault damage zone featuring imbricate structures and strain partitioning. Mandal et al. (2019) presented U–Pb and Nd isotope data confirming Paleoproterozoic ages for Bhimtal Volcanics (~1860 Ma) and Amritpur Granite (~1900 Ma), with Lesser Himalayan duplex thrusting accommodating 541–575 km of shortening. Agarwal et al. (2021) used AMS on the "undeformed" Amritpur Granite to reveal subtle Himalayan fabrics, redefining it as a tectonic sliver rather than a klippe. Kumar et al. (2024) reviewed petrotectonic evolution, noting mineralization potential in mafic volcanics and granite contacts.

8.2.0 OBSERVATION AND RECOMMENDATIONS OF PREVIOUS WORK

8.2.1 Based on the review of published literature, previous geological studies, petrographic–mineragraphic analyses, and available geochemical datasets, several significant observations have emerged regarding the mineral potential of the Amritpur block.

8.2.2 Available geochemical data from reconnaissance-level studies indicate the presence of significant polymetallic anomalies in the study area. Elevated concentrations of base metals have been reported from basic to ultrabasic rocks, quartz veins and structurally controlled shear zones. The important geochemical observations include, **Copper (Cu)** values reaching up to **2000 ppm, Zinc (Zn)** values up to **2250 ppm, Lead (Pb)** values in the range of **250–500 ppm, Silver (Ag)** values up to **10 ppm**

8.2.3 In addition to the base metals, elevated concentrations of **Ni and Co** have also been reported in association with mafic and ultramafic lithologies. These metal associations, coupled with favourable alteration signatures, indicate the possibility of a **hydrothermal system with affinities to volcanogenic massive sulphide (VMS) type mineralisation**.

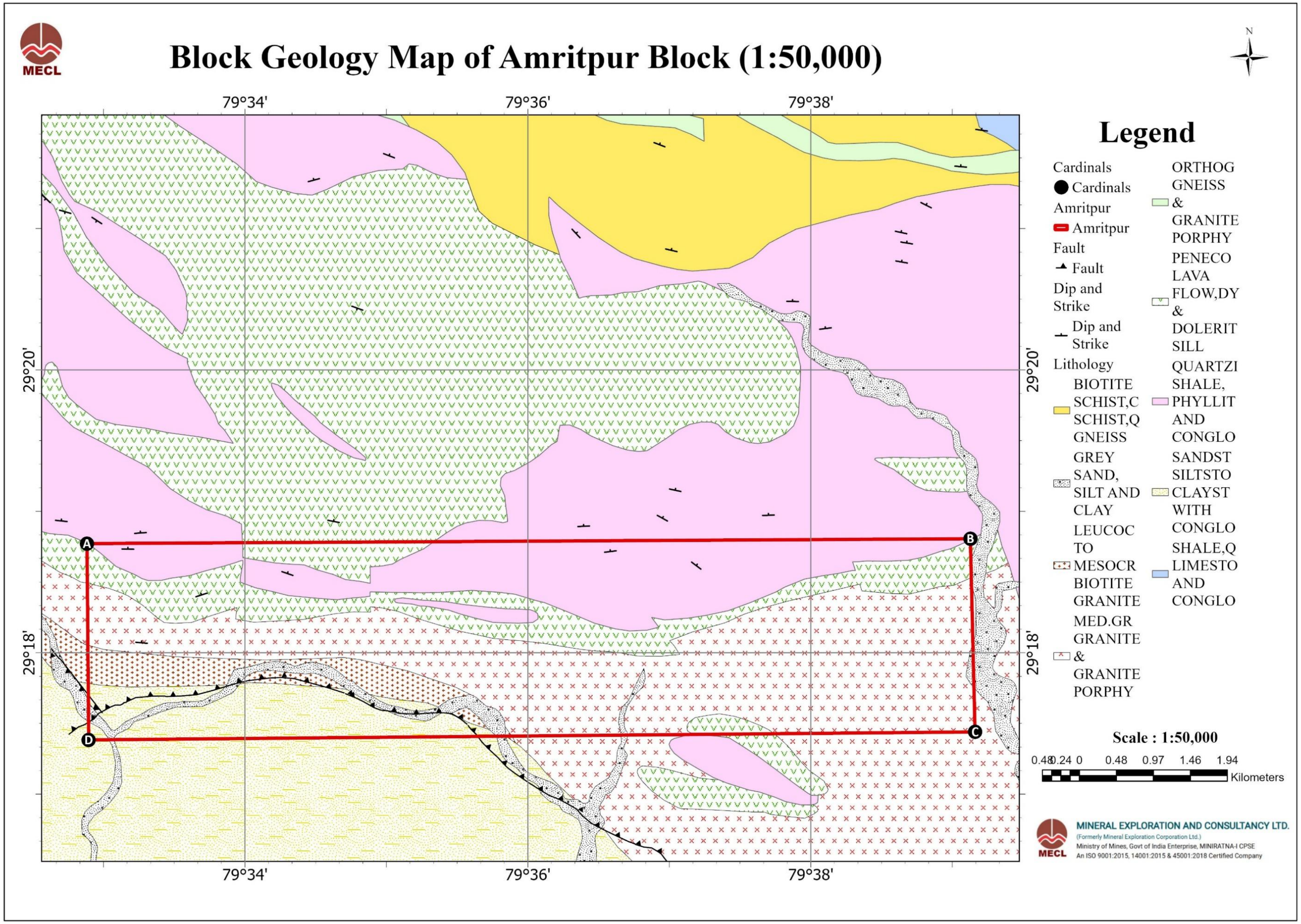
8.2.4 Alteration indices derived from lithogeochemical data further support the presence of hydrothermal alteration processes affecting the volcanic and intrusive rocks in the area.

8.2.5 Mineragraphic studies of selected samples from the block indicate the presence of sulphide mineralization in both vein-type and disseminated modes. The principal ore minerals identified include, **Chalcopyrite, Pyrite, Galena, Sphalerite.** These sulphide minerals occur as, thin to moderately thick **veins and veinlets, fracture fillings, fine disseminations** within host rocks, and patches associated with **hydrothermal alteration zones.** The presence of secondary oxidation minerals such as **goethite and limonite** suggests supergene alteration of primary sulphide phases. The mineral assemblage is typical of polymetallic hydrothermal systems and indicates a favourable metallogenic environment.

8.2.6 Structural analysis of the region highlights the important role of major tectonic structures in controlling mineralisation. The Amritpur area lies within the tectonically active Lesser Himalayan fold–thrust belt where several regional structures influence the geological architecture. Tectonic structures such as: **Main Boundary Thrust (MBT), Salari Thrust,** Associated **shear zones and fracture systems, Contacts between granitoids and volcanic–sedimentary sequences.**

8.2.7 These structures are interpreted to have acted as **conduits for hydrothermal fluids**, facilitating the mobilisation and deposition of metallic minerals. The interaction of hydrothermal fluids with reactive host rocks along these structural pathways likely led to the development of sulphide mineralisation within veins, fractures and altered wall rocks.

8.2.8 Based on the lithological, geochemical and mineralogical characteristics observed in the area, previous studies suggest that the mineralisation may represent **reworked hydrothermal mineralisation** associated with Paleoproterozoic volcanic and intrusive rocks. The mineralisation is interpreted to have originated from **volcanogenic hydrothermal processes**, possibly related to **VMS or SEDEX-type systems**, developed within volcanic–sedimentary sequences. Subsequent tectonic events during the **Himalayan orogeny** likely resulted in: (i) structural reactivation, (ii) remobilisation of sulphide minerals, (iii) redistribution of metals along thrusts, shears and fractures. This tectono-hydrothermal reworking may have enhanced the concentration of metals within structurally controlled zones.



Text Figure 8.1- Regional Geological Map at 1:50000 (NDGR)

CHAPTER-9

GEOCHEMICAL OR GEOPHYSICAL DATA

9.1.0 GEOCHEMICAL DATA

9.1.1 The primary samples have been analysed i.e., Cu-Pb-Zn & Ag by AAS, Au by Fire-Assay (Au), 34 elements and trace elemental analysis , i.e., Ga, Cr, Co, Ba, Sr, Rb, Z, Y, Nb, Ce, Nd, Ta, Cd, Sb, Sc, As, Th, Cu, Ag, Au, As, Mn, Ti, V, Cr, Ni, Pb, Zn, Sb, Sn, Mo, W, Cd, Co by ICP-MS and 10 Major Oxides i.e. SiO_2%, Al_2O_3%, Na_2O%, K_2O%, CaO%, MgO%, Fe_2O_3(T)%, MnO%, TiO_2%, P_2O_5%, SO_3% & LOI% by XRF. The analyses were conducted on 131 bedrock samples, 100 samples for AAS, 10 samples for Fire-Assay, ICP-MS analysis quantified 34 elements performed on 42 samples, 20 samples are undergone for XRF and Mineral phases Analysis done by XRD on 10 samples. The results of the chemical analysis are shown in Annexure-II to Annexure-V & Annexure-VI for XRD results.

9.1.2 To quantify the geochemical characteristics of dominant lithologies and assess the mineral potential in the area, selected samples were crushed, homogenized by coning and quartering, and powdered to -200 mesh. Approximately 200 grams of each sample were sent for analysis to determine for Polymetals mineralization and other respective studies mentioned. All analyses were conducted by the Chemical Laboratory at MECL (a NABL accredited laboratory), Nagpur. The geochemical data of the samples were plotted on lithological Map to better understand chemical signatures and Polymetals (Cu-Pb-Zn-Ag & Au) anomalies in the region.

9.1.3 Four-element dataset (100 samples) shows that most samples fall in the low to moderate range (Cu generally <200 ppm, Zn commonly <200–300 ppm, Pb usually <100 ppm, Ag in tens to a few hundred ppb), defining the geochemical background. Superimposed on this background are a few high-tenor anomalies, which define the current primary exploration targets. The notable copper anomalies are:

- Sample ABL/BR/67: **Cu 4909 ppm** (0.49%), Pb 17 ppm, Zn 43 ppm, **Ag 188 ppb**, representing the strongest Cu anomaly in the present dataset.
- Sample ABL/BR/64: **Cu 2105 ppm** (0.21%), Pb 63 ppm, Zn 4 ppm, **Ag 994 ppb**, indicating combined Cu–Ag enrichment.

9.1.4 The other anomalies recorded in the regions are: ABL/BR/01: **Zn 961 ppm**, ABL/BR/083: **Pb 1518 ppm,** AB/BR/043: **Au 373 ppb,** ABL/BR/066: **Au 350 ppb** ABL/SSS/07: **Ag 2153 ppb,** ABL/BR/07: **Ag 1225 ppb.**

9.1.5 Several samples are characterized by high Pb and Ag with relatively low Cu–Zn, indicating localized Pb–Ag shoots, for example: ABL/BR/30: **Pb 1252 ppm,** Zn 38 ppm, **Ag 482 ppb**, Cu 78 ppm, ABL/BR/31: **Pb 1055 ppm,** Zn 15 ppm, **Ag 498 ppb**, Cu 86 ppm, ABL/BR/54: **Pb 1285 ppm**, Zn 48 ppm, **Ag 716 ppb,** Cu 51 ppm.

9.1.6 The trace elements analysis has shown that the Cu-rich sites are also anomalous in Co, Ni and high field strength elements, together with elevated REE contents, particularly in mafic hosts, ABL/BR/67: high Cu is accompanied by Co ~11.9 ppm, Ni ~46.6 ppm, and elevated Zr, La, Ce and Nd, indicating a mafic–intermediate, REE-enriched host with significant sulphide and Fe-oxide development. ABL/BR/64: Cu-rich, with elevated Co–Ni and W–Mo and high total REE, suggesting structurally focused metal enrichment in an Fe-oxide–bearing, evolved mafic zone. Pb–Ag-rich samples typically show comparatively higher As–Sb–Bi and W–Mo relative to background, compatible with your observation of galena-bearing veins and minor sulfosalts in structurally controlled zones.

9.1.7 The whole-rock major-oxide data for 20 representative bedrock samples indicate two principal geochemical and lithological host domains.

- **Felsic to intermediate, silicic rocks:** These samples (e.g., ABL/BR/25, ABL/XRD/06) have SiO_2 typically 58–70%, Al_2O_3 ~15–19%, K_2O commonly 5–9%, with comparatively lower MgO and CaO and moderate Fe_2O_3 (6–8%). They correlate with quartzites, granites and rhyodacitic units mapped in the Nagthat Formation and Amritpur Granite Complex, particularly near intrusive and contact zones.

- **Fe–Mg-rich mafic rocks:** Mafic samples (e.g., ABL/BR/50, ABL/BR/61) show lower SiO_2 (~38–47%) and markedly higher Fe_2O_3 (up to ~21%), MgO (5–10%) and CaO (6–16%), consistent with metabasalts, amphibolites and chlorite–amphibole schists of the Bhimtal Volcanics. These units coincide spatially with many of the Cu-rich and Fe-oxide-rich sites, and petrography/mineragraphy confirm abundant hematite, ilmenite and pyrite in these rocks.

9.2.0 GEOPHYSICAL DATA

9.2.1 Geophysical survey has not been carried out in the block, and there is no available NGPM data of GSI for the present exploration block.

CHAPTER-10

EXPLORATION UNDERTAKEN DURING CURRENT INVESTIGATION

10.1.0 INTRODUCTION

10.1.1 The (G-4) reconnaissance survey for polymetals (Cu-Pb-Zn, Au-Ag) in Amritpur Block (25.77 sq km), Nainital District, Uttarakhand, was executed by Mineral Exploration & Consultancy Limited (MECL) under NMEDT. Fieldwork spanned from May to October 2025, covering geological mapping at 1:12,500 scale over 25.77 sq km, collection of 131 samples, for bedrock and stream sediment samples, and structural data logging at 150 stations. No trenching or drilling was undertaken due to reconnaissance scope, terrain challenges, and forest cover; all activities prioritized non-invasive surface methods compliant with environmental norms.

10.1.2 India holds limited domestic reserves of critical metals like copper (Cu), lead (Pb), zinc (Zn), silver (Ag), and gold (Au), essential for electronics, batteries, alloys, jewelry, and renewable energy sectors. As per IBM Indian Mineral Year Book 2024, total resource stand at Cu: 21.18 MT (ore), Pb-Zn: 85.47 MT (ore), Ag: 972 tonnes (metal), Au: 504 tonnes (metal), with production gaps driving imports (Cu: 5.5 MT imported vs. 0.48 MT produced; Pb-Zn: heavy reliance). Global demand surges (world Cu production ~22 MT/year, Zn ~13 MT, Pb ~4.5 MT, Ag ~27,000 tonnes, Au ~3,000 tonnes), underscoring exploration needs. (Indian Mineral Year Book, IBM-2024).

10.1.3 India's polymetal resource are modest: Cu ore 21.18 MT (mostly Andhra Pradesh, Rajasthan, Jharkhand); Pb-Zn ore 85.47 MT (Rajasthan 80%); Ag ~972 t (associated with Pb-Zn/Cu); Au ~504 t (Karnataka, Bihar). Uttarakhand holds minor Cu-Pb-Zn prospects in Lesser Himalaya. Grades vary: Cu 0.5-2%, Zn-Pb 3-10%; low-grade dominates (~60%), needing beneficiation.

10.1.4 In 2023-24, production: Cu concentrates ~1.4 MT (ore ~4 MT), Pb-Zn concentrates ~3 MT (ore ~7 MT), Ag ~800 t, Au ~3 t. Apparent consumption far exceeds: Cu ~5 MT, Pb-Zn ~6 MT, Ag ~3,000 t, Au ~800 t. Imports: Cu 5.5 MT (Chile 40%, Japan 15%), Pb-Zn 4 MT (Australia, Peru), Ag/Au significant. Exports negligible. Total demand ~8.90 MT/year (Cu 5 MT, Pb-Zn 3.5 MT, Ag/Au minor). Domestic supply ~1.20 MT/year; imports ~7.70 MT. gap fuels vulnerability; govt. promotes exploration, Joint Venture mining abroad, private sector entry to bolster EV/renewables/agri sectors.

10.1.5 World production of Cu-Pb-Zn-Ag & Au in Top 7 countries for the year 2023 are tabulated below in Table 10.1 (Indian Mineral Year Book, IBM-2024). It is evident from the figures that the Production these metals are low in India. So, the exploration of these critical metals is very much required to increase the production and to meet the demand.

Table-10.1:
World Production of Polymetals (Cu-Pb-Zn-Ag & Au), by Principal Countries (Indian Mineral Year Book, IBM-2024).

Country	Cu (2023), mt	Zn (2023), mt	Pb (2023), mt	Ag (2023)	Au (2023)
World	22,000	13,000	4,500	26,000	3,000
China	1,800	4,000	1,700	3,500	400
Peru	2,600	1,400	300	1,000	120
Australia	800	1,200	500	500	320
Chile	5,400	500	20	1,300	40
USA	1,200	700	300	900	170
Russia	900	250	400	1,300	330

10.1.6 Polymetals are vital for India's electronics (Cu/Ag), batteries (Pb/Zn), renewables (all), economy. Deficient reserves demand intensified GSI/MECL efforts; Uttarakhand's Himalayan prospects (volcanics-granite hosted sulphides) offer potential. Accordingly, Govt. of India, State Governments, Exploration Agencies like GSI, MECL etc. are taking several steps to enhance the exploration programme in this direction. Therefore, detailed exploration is necessary for conversion of remaining resources into reserves.

10.1.7 Accordingly, MECL received consent from DGM, Uttarakhand, to explore areas with promising polymetal potential, marking significant progress in the exploration of fertilizer resources. MECL identified the exploration block through a desktop study, and the proposal was deliberated in the 6th meeting of the Technical-cum-Cost

Committee (TCC-II), National Mineral Exploration and Development Trust (NMEDT), held on 27th & 28th Feb 2025.

10.1.8 The TCC-II committee technically evaluated the proposal for its geological components and suitability in the G-4 stage of exploration. The committee recommended the proposal for approval at the 41st Executive Committee (EC) NMEDT meeting on 10th March 2025. Following approval, MECL conducted the G-4 Reconnaissance Survey in the Amritpur Area, including geological mapping, surface sampling, and associated laboratory studies. Surveys were conducted between May 2025 to October 2025, with successful completion of mapping across 25.77 sq. km and a detailed analysis of bedrock samples. The field activities underwent a technical review during the 25th TCC-II meeting of NMEDT.

10.2.0 OBJECTIVE

10.2.1 The exploration is proposed with the following objectives:

a) Preparation of Geological map on 1:12,500 Scale.
b) Surface Sampling for bedrock as Chips/grabs from veins/sulphides and Stream sediments from nallas.
c) To prove the mineralized zones by bedrock/channel sampling from outcrops and associated rocks and to study their lateral and vertical relationship.
d) To upgrade the block and facilitate the state govt. for auctioning of the block.

10.2.2 The details of the nature and quantum of work proposed vs actual achievement is given in Table-10.2.

Table – 10.2:

Proposed Quantum of Work vs. Actual achievement by MECL in Amritpur Area, District: Nainital, Uttarakhand

Sl. No.	Item of Work	Unit	Proposed Quantum of work	Achievement
1	Geological Mapping (on 1:12,500 Scale)	Sq. km	25.77 Sq. Km	25.77 Sq. Km
2	**Bedrock Sampling**			
	Rapid Geochemical Analysis by AAS method: Cu-Pb-Zn-Ag	Nos	150 (100 Bedrock + 50 Trench	100
	Gold Analysis by Fire-assay: Au	Nos	10	10
	IC-PMS; 34 Elemental Study - As, Sb, Mo, Co, Ni, Sn, Hf, Nb, Ta, Ge, W, Ti, Zr, Se, Te, Cs, Y, Rb, Sr, and REEs: La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu.	Nos	50	42
	SiO_2%, Al_2O_3%, Fe_2O_3%, MnO%, MgO%, CaO%, Na_2O%, K_2O%, P_2O_5%, TiO_2%, SO_3%, & LOI% by XRF	Nos	20	20
	External Check of Cu-Pb-Zn-Ag	No	15	10
	External Check for Au	No	1	1
	External Check for ICPMS	No	5	4
	External Check for Major Oxide	No	2	2
	XRD	Nos	10	10
4	Petrological Samples	Nos	10	10
	a) Preparation of Thin Section	Nos	10	05
	b) Study of Thin Section	Nos	10	05
5	Mineragraphic Study	Nos	20	20
	a) Preparation of Polished Section	Nos	20	20
	b) Study of Polished Section	Nos	20	20
6	Excavation (Trench)	Cu.m	100	0
7	Report Preparation (Digital Format)	Nos.	1	1

10.3.0 DETAILS OF GEOLOGICAL MAPPING

10.3.1 To achieve the objectives mentioned in (10.3.0), the methodology adopted includes literature review and first-generation geological map using satellite images coupled with the google earth images and topographic maps. This was followed by contact mapping in Amritpur Area from Amritpur, Amiya, Salari areas, of dist: Nainital, Uttarakhand using GPS and other geological field equipment. A total of 25.77 Sq. km mapping on 1:12,500 scale was completed.

10.4.0 DETAILS OF SURFACE SAMPLING, TRENCHING, DRILLING, ETC.

10.4.1 Considering the favourable geological setting of the Amritpur block within the Lesser Himalayan tectonic domain, the presence of polymetallic geochemical anomalies, sulphide mineralisation and structurally controlled hydrothermal alteration zones, the area warrants systematic exploration. The present G-4 stage exploration programme will cover detailed geological mapping at 1:12,500 scale, systematic bedrock sampling from outcrops and altered zones, comprehensive multi-element geochemical analysis, and integrated petrographic, mineragraphic and alteration studies. These investigations will enable the identification and delineation of high-priority mineralised zones within the block.

10.4.2 The outcome of the present exploration programme will provide a scientific and geologically constrained database for evaluating the mineral potential of the Amritpur block. The results will assist in identifying prospective targets and upgrading the exploration stage of the block to G-3 level, thereby facilitating further detailed exploration and eventual resource estimation in accordance with the guidelines of NMEDT. Based on the review of available literature, previous geological studies, petrographic–mineragraphic investigations and geochemical datasets, the Amritpur block shows encouraging indications of polymetallic mineralisation associated with hydrothermal processes, which justifies the implementation of the present G-4 exploration programme.

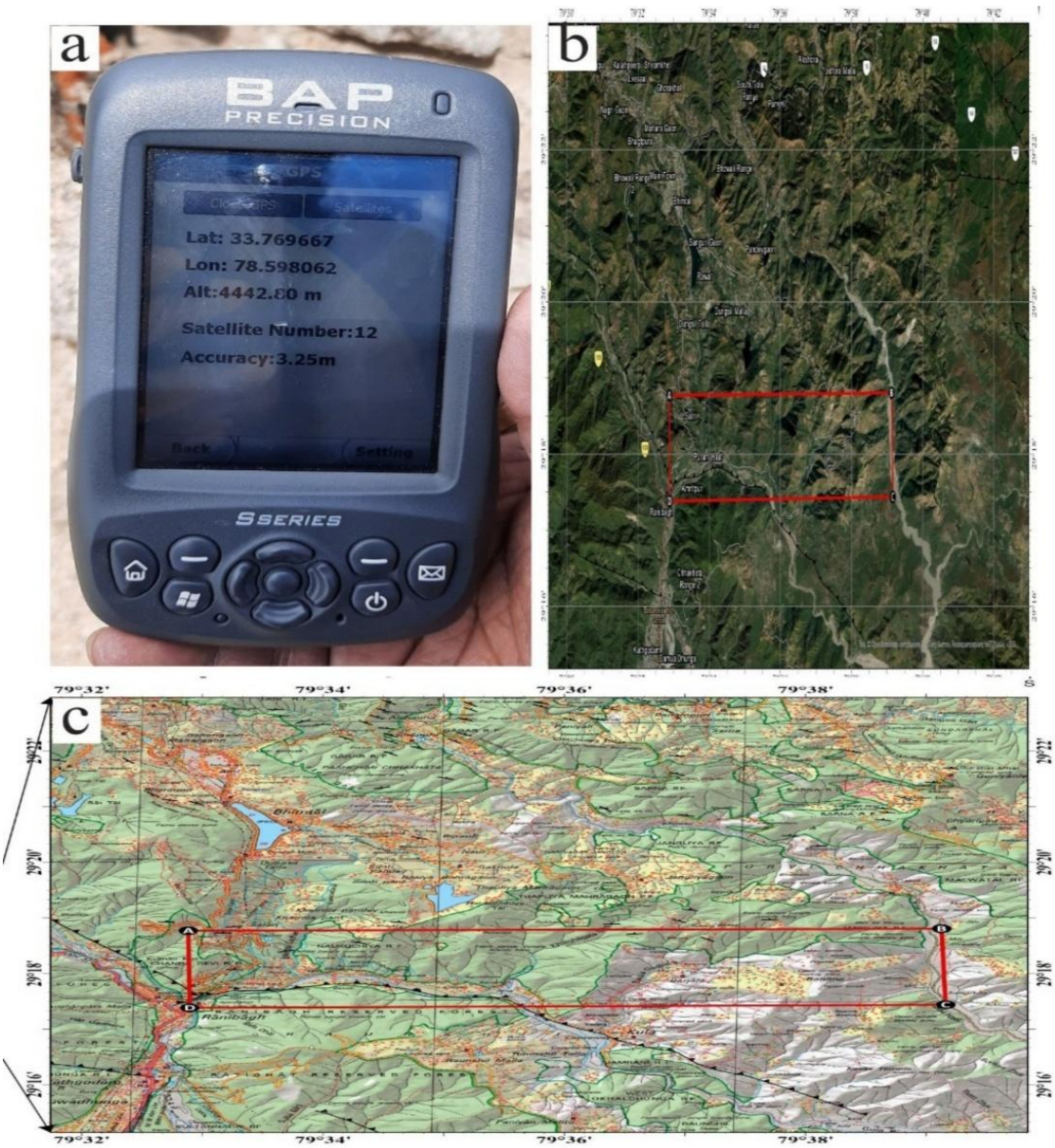
10.4.3 A total of 131 primary bedrock samples were analysed for AAS, Fire-Assay, ICP-MS, XRF and 10 samples were analysed for XRD studies. Additionally, 10 samples were studied for petrography, and 20 for Mineragraphic studies. The geological outcrop mapping on 1:12,500 scale (Plate-III), surface sampling of 131 bedrock samples (Plate-IV), and other associated geological like DEM Map (Plate-V) and analytical work are associated with Annexure-I to IX. The complete chemical analysis of surface samples is tabulated from Annexure-I to Annexure-V.

CHAPTER-11

LOCATION OF DATA POINTS

11.1.0 ACCURACY AND QUALITY OF SURVEY USED TO LOCATE BLOCK BOUNDARY

11.1.1 The entire survey work has been carried out with the help of GPS (Make-BAP Precision), Model- 'S' series) and surface features i.e., roads, village boundaries, temples/mosque, ponds, river/nalas and block boundary co-ordinates has been determined by toposheets. The photograph of GPS is given in Photo-11.1.



Photograph 11.1 : a). GPS (Make-BAP Precision), Model - 'S' series). b). Toposheet No. 53O/11 used with the advanced Navigation applications for appropriate sampling. c). Google Earth Imagery used to see area and nearby village details.

Table 11.1: Co-ordinates of Cardinal Points of the block boundary of Amritpur (G-4) Area. Dist.: Nainital, Uttarakhand

Block Cardinal Points	Datum: WGS-84				Elevation (m)
	Geographic (DD°MM'SS.SS")		UTM Zone-44 (m)		
	Latitude	Longitude	Easting (m)	Northing (m)	
A	29° 18′ 46.33″ N	79° 32′ 53.02″ E	359,001	3,243,525	1093
B	29° 18′ 48.35″ N	79° 39′ 7.67″ E	369,109	3,243,466	995
C	29° 17′ 26.38″ N	79° 39′ 9.64″ E	369,134	3,240,942	944
D	29° 17′ 23.00″ N	79° 32′ 53.74″ E	358,989	3,240,959	575

11.2.0 QUALITY AND ADEQUACY OF TOPOGRAPHIC CONTROL

11.2.1 Block boundary co-ordinates, elevation points and sample points were surveyed by GPS. The topographic surface features, and contours survey by area Toposheet. Positional (horizontal) accuracy of the GPS is ±5-10 m while the elevation (vertical) accuracy is ±10-20 m. The detailed geological map of Amritpur block was prepared on 1:12,500 scale.

CHAPTER-12

SAMPLING TECHNIQUE

12.1.0 NATURE AND QUALITY OF SAMPLING AND MEASURES TAKEN TO ENSURE SAMPLE REPRESENTATIVE

12.1.1 The sampling strategy for the G-4 Exploration Project targeting Polymetals (Cu-Pb-Zn-Ag & Au) in the Amritpur Area was designed to ensure the collection of representative samples across the investigated area.

12.2.0 SAMPLING METHODS

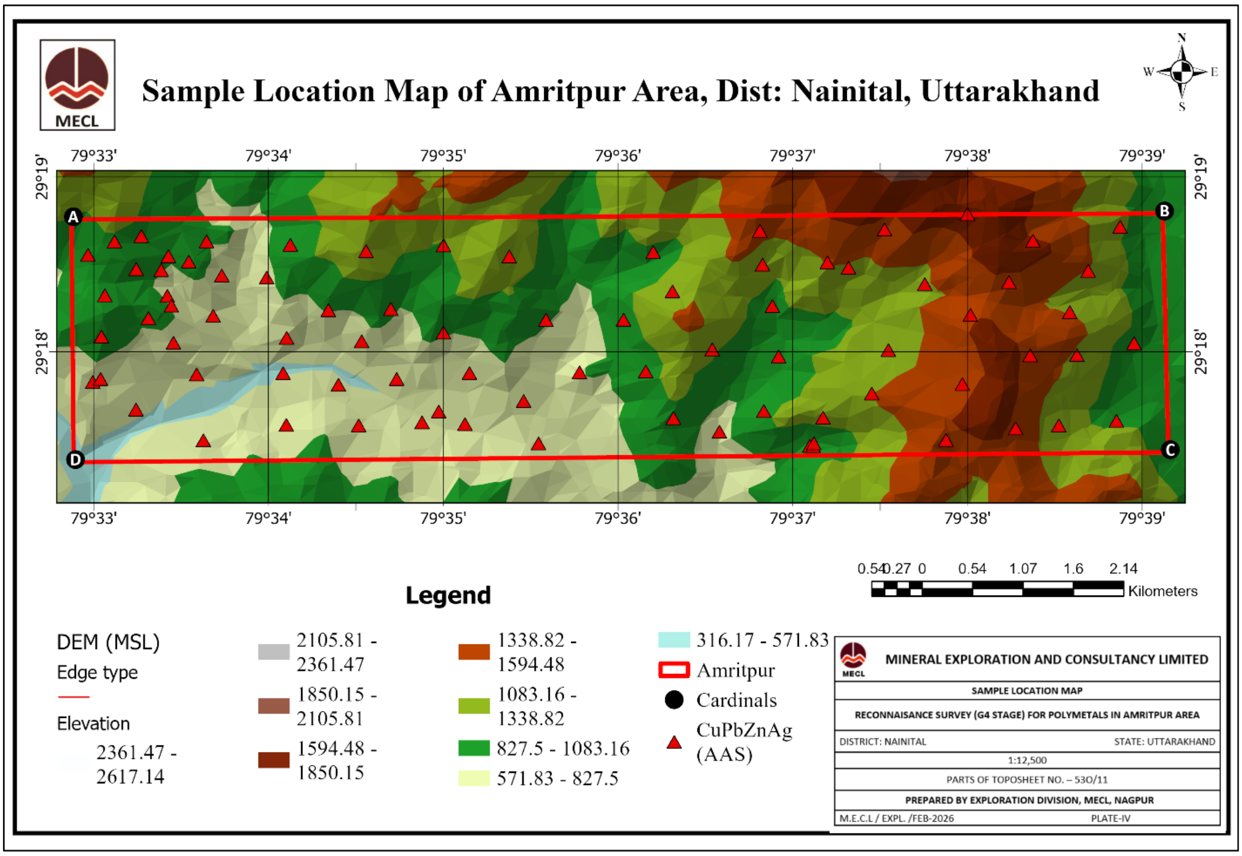
12.2.1 Detailed geological mapping was conducted to understand the geological setup to target mineralization, focusing on rock types, known mineral occurrences, and structural features. The sampling density was prepared based on 1:12,500 scale. Denser sampling grids were employed in areas with probable zones. However, sampling was not feasible in the extrapolated strike due to the dense and inaccessible forest, and in the north-central sector of the block, the ore body may be concealed by thick-dense forest valley. Further, surface samples were collected for bedrock and stream sediments. The sample density and the relative terrain to it shown in the Text-Figures 12.1. The samples were analysed by AAS, FIRE-ASSAY, ICP-MS, XRF and physical studies of mineral phases in petrography, mineragraphy and XRD. Bedrock (Block/grab) samples were taken with the help of sledge hammer and chisel.

12.2.2 During the sampling, surface was properly cleaned and each sample was collected in separate plastic bags with proper labelling. After collecting each sample, all the instruments were properly cleaned before proceeding for next sample collection to maintain quality and to avoid contamination.

12.2.3 To ensure that the collected samples accurately represented the lithounits in the Amritpur Area, precise documentation of sample locations, standardized sampling procedures were implemented. Precise recording of sample locations using GPS coordinates or detailed mapping ensures proper spatial representation. Standardized sampling protocols were followed for sample size, collection depth, and sample handling to maintain consistency throughout the block.

12.2.4 A total of 131 bedrock samples including chips/channel samples were collected for chemical analysis, 10 no. collected for Petrography, 20 samples for Mineragraphy and

10 samples collected for XRD. The Analysis for both has been done in MECL laboratory, Nagpur. The value of the analysis has been given in (Annexure - II to VI).



Text Figure 12.1: Sample Location Map showing the density of the samples in the block with Digital elevation Model (DEM).

CHAPTER-13

DRILLING TECHNIQUES AND DRILL SAMPLING EMPLOYED

13.1.0 DRILLING TYPES AND DETAILS

13.1.1 The present exploration was carried out for Polymetals (Cu-Pb-Zn-Ag & Au) in Amritpur Area with only geological mapping and sampling. Thus, drilling was not carried out in this block.

CHAPTER-14

SUB SAMPLING TECHNIQUES AND SAMPLE PREPARATION

14.1.0 WHETHER RIFFLED, TUBE SAMPLED, ROTARY SPLIT, ETC., AND WHETHER SAMPLED WET OR DRY.

14.1.1 During the present exploration, a total of 131 nos. of primary samples were collected, 17 nos. of external check samples were prepared. The primary and external check samples have been analysed for Cu-Pb-Zn & Ag by AAS, Au by Fire-Assay, 34 elements and trace elemental analysis , i.e., Ga, Cr, Co, Ba, Sr, Rb, Z, Y, Nb, Ce, Nd, Ta, Cd, Sb, Sc, As, Th, Cu, Ag, Au, As, Mn, Ti, V, Cr, Ni, Pb, Zn, Sb, Sn, Mo, W, Cd, Co including REEs by ICP-MS and 10 Major Oxides i.e. SiO_2%, Al_2O_3%, Na_2O%, K_2O%, CaO%, MgO%, Fe_2O_3(T)%, MnO%, TiO_2%, P_2O_5%, SO_3% & LOI% by XRF and mineral phases identifications by XRD in Chemical Laboratory of MECL, Nagpur. The, external check samples have been analysed for all the above chemical procedure at Jawaharlal Nehru Aluminium Research Development and Design Centre, (JNARDDC) Nagpur (A Government Laboratory).

14.2.0 NATURE, QUALITY AND APPROPRIATENESS OF THE SAMPLE PREPARATION TECHNIQUE

14.2.1 The details of sampling procedure for primary samples are described in Para Quality of the sample preparation is maintained by proper cleaning, maintenance of the equipment and proper crushing, sieving and coning and quartering of samples. For sample preparation proper technique and expertise has been used.

14.3.0 QUALITY CONTROL PROCEDURES ADOPTED

14.3.1 The primary samples have been collected from entire probable mineralized zones and the samples have been prepared at centralized mechanized sampling unit, Nagpur. The standard sampling procedure in supervision of qualified sampling technician has been adopted to control the quality of samples. Similarly, external check samples have also been prepared under the supervision of qualified sampling technician following the standard sampling procedure.

14.4.0 MEASURES TAKEN TO ENSURE THE SAMPLING IS REPRESENTATIVE OF THE IN-SITU MATERIAL COLLECTED

14.4.1 All the primary samples have been marked and prepared for Cu-Pb-Zn-Ag & Au by AAS, Fire-Assay, ICP-MS, XRF and XRD. Precise recording of sample locations using GPS coordinates or detailed mapping ensures that the samples collected represent specific areas within the block. This allows for spatial correlation and analysis of variations across the area. Proper cleaning of the sampling surface before collecting each sample minimizes contamination from previous samples or external sources. Using separate plastic bags with proper labelling for each sample ensures traceability and reduces the risk of mix-ups. These practices promote consistency throughout the sampling process.

14.4.2 The measures outlined here are some challenges associated with obtaining representative samples and in-situ samples, heavy rainfall creates more valleys and more debri on surface of the designated block. Rainfall movement can scour and mix materials from various litho-units, potentially leading to samples that don't accurately reflect the underlying bedrock composition. Bedrock chip samples collected from vertical sections/exposer to avoid the mixture of materials from different sources and channel samples were taken nearly 6-8 inches deep on vertical sections across 1 to 2 meters length. In Amritpur Area, the sampling done for Bedrock and Stream Sediments only, to avoid the instu problems of rainfall debris in Stream samples and more appropriately targeting the source rock.

14.5.0 WHETHER SAMPLE SIZES ARE APPROPRIATE TO THE GRAIN SIZE OF THE MATERIAL BEING SAMPLED

14.5.1 Standardized exploration practices typically establish guidelines for sample size based on the target material and exploration stage. Considering the potential presence of hilly terrain of the region, the grain size of the collected materials was variable in grain size of the bedrock samples. However, stream sediments/clay are of finer grain sizes relatively. The primary samples have been prepared (–) 200 mesh size and all the other samples have been prepared from primary samples.

CHAPTER-15

QUALITY OF ASSAY DATA AND LABORATORY TESTS

15.1.0 THE NATURE, QUALITY AND APPROPRIATENESS OF THE ASSAYING AND LABORATORY PROCEDURES

15.1.1 The primary samples have been analysed i.e., Cu-Pb-Zn & Ag by AAS, Au by Fire-Assay, 34 elements and trace elemental analysis , i.e., Ga, Cr, Co, Ba, Sr, Rb, Z, Y, Nb, Ce, Nd, Ta, Cd, Sb, Sc, As, Th, Cu, Ag, Au, As, Mn, Ti, V, Cr, Ni, Pb, Zn, Sb, Sn, Mo, W, Cd, Co including REEs by ICP-MS and 10 Major Oxides i.e. SiO_2%, Al_2O_3%, Na_2O%, K_2O%, CaO%, MgO%, Fe_2O_3(T)%, MnO%, TiO_2%, P_2O_5%, SO_3% & LOI% by XRF and mineral phases identifications by XRD in Chemical Laboratory of MECL (a NABL accredited laboratory) and Jawaharlal Nehru Aluminium Research Development and Design Centre, (JNARDDC) Nagpur (A Government Laboratory).

15.2.0 ICP-MS ANALYTICAL METHODS AND PROCEDURES

15.2.1 Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) was employed for the quantitative analysis of primary and trace elements in geochemical samples collected for the G-4 exploration project. This analytical technique utilizes an 'Agilent' make 'ICP-MS 7800' instrument and offers exceptional detection capabilities, ranging from low-concentration analyses in the parts per billion (ppb) and parts per trillion (ppt) range to measurements of elements present in parts per million (ppm) concentrations. The accuracy and precision (standard deviation) achieved for polymetallic mineralization were either excellent (<5%) or good (5-10%).

15.3.0 SAMPLE PREPARATION

15.3.1 Prior to sample analysis, the ICP-MS instrument was meticulously calibrated using certified reference materials (CRM) such as NCSDC-73022. A standardized dissolution procedure involving hydrochloric acid (HCl), hydrofluoric acid (HF), and nitric acid (HNO_3) was employed for sample preparation. This process was carried out within screw-top Teflon bombs using a microwave digester to ensure complete dissolution of the geochemical materials.

15.4.0 LABORATORY SAFETY MEASURES

15.4.1 Throughout the chemical analysis process, stringent laboratory safety protocols were strictly followed. These protocols included:

a) Mandatory use of department-approved safety goggles and apron attire within the laboratory environment.

b) Consistent utilization of fume hoods when handling hazardous or potentially irritating chemicals.

c) Clear and accurate labeling of all containers to ensure proper identification of their contents.

d) Adherence to the "once-a-container" principle, where chemicals are never returned to their original containers after exposure.

e) Minimization of chemical usage, employing clean and dry spatulas for chemical retrieval, and proper disposal of excess materials.

f) Implementation of appropriate precautions to avoid burns, including the use of beaker tongs for handling hot containers.

g) Immediate rinsing of any chemical spills on the skin with copious amounts of water.

h) Prompt cleanup and disposal of broken glassware in designated areas.

i) Observance of designated waste disposal procedures, with specific protocols for liquid and solid waste materials.

15.5.0 QUALITY CONTROL PROCEDURES

15.5.1 To ensure the accuracy and reliability of the analytical data, a comprehensive suite of quality control (QC) procedures was systematically implemented during the analysis of the radicals. These procedures encompassed:

a) Analysis of certified reference materials and measurement standards to verify instrument calibration and analytical accuracy.

b) Inclusion of blind samples within the analytical batch to assess potential biases introduced during sample preparation or analysis.

c) Utilization of QC samples and control charts for continuous monitoring of analytical performance.

d) Analysis of blanks to detect and quantify any potential background contamination arising from reagents or instrument processes.

e) Analysis of spiked samples to evaluate matrix effects and overall analytical recovery.

f) Performance of duplicate analyses and the use of internal check standards to assess data precision and consistency.

S.N.	Lab No.	Cu	Pb	Zn	Ag
		PPM (DL = 1 PPM)			PPB (DL = 10 PPB)
1	BLANK-1	<1	<1	<1	<10
2	BLANK-2	<1	<1	<1	<10
3	BLANK-3	<1	<1	<1	<10
4	BLANK-4	<1	<1	<1	<10
5	BLANK-5	<1	<1	<1	<10

15.6.0 XRF ANALYTICAL METHODS AND PROCEDURES

15.6.1 X-ray fluorescence (XRF) spectroscopy was employed for the geochemical analysis of bulk rock samples collected for the Amritpur Area G-4 Exploration project. This technique utilizes an 'Axios mAx XRF' instrument (Panalytical make) to determine the elemental composition of the samples. In Amritpur Area samples XRF studies has been done for Major Oxides SiO2%, Al2O3%, Fe2O3%, Na_2O%, K_2O%, P_2O_5%, MgO%, MnO%, CaO%, TiO_2%, LOI.

a) Model - Axios mAx.

b) Make – Panalytical

c) Pellet preparation-Hydraulic Press

d) Standards (CRM) - NCSDC-16006

15.7.0 PELLET PREPARATION

15.7.1 Standardized pellet preparation method was used to ensure sample homogeneity and consistency for XRF analysis. This process involved the following steps:

a) **Sample Grinding:** Each sample was pulverized to a fine powder using a grinding mill to achieve a particle size of less than 200 mesh.

a) **Hydraulic Press Pellet Formation:** A precisely weighed portion of the pulverized sample (5 grams) was mixed with 10 grams of boric acid, acting as a binding agent.

b) The mixture was then pressed into a 40 mm diameter pellet using a hydraulic press at a pressure of approximately 20-22 tons.

15.8.0 INSTRUMENT CALIBRATION AND ANALYSIS

15.8.1 Prior to sample analysis, the XRF instrument was meticulously calibrated using certified reference materials (CRM) such as GBW07103 and GBW07105. This calibration ensured the accuracy and reliability of the measured elemental concentrations. Following calibration:

a) The prepared pellet was placed in the designated sample holder of the XRF instrument.

b) The instrument settings were verified to ensure adherence to established protocols.

c) XRF analysis was initiated using the instrument software, automatically controlling the measurement process.

d) The XRF instrument bombarded the sample with X-rays, causing the atoms within the sample to emit characteristic fluorescent X-rays.

e) The emitted X-rays were detected and analysed by the instrument, generating quantitative data on the elemental composition of the sample.

15.9.0 DATA RECORDING AND QUALITY CONTROL

15.9.1 The results obtained from the chemical analysis were documented in a comprehensive report. This report detailed the elemental concentrations for each sample, along with relevant information regarding the analysis conditions. Additionally, the software embedded within all the instruments involved in analysis performed intermediate checks using a dedicated bead standard, further ensuring the quality and consistency of the analytical data.

15.10.0 LOSS ON IGNITION (LOI)

15.10.1 The weight loss on ignition (LOI) technique was employed to determine the number of volatile components present within the rock samples. This analysis followed the WCL procedure, which involved:

15.10.2 Precisely weighing a dried sample (previously oven-dried at 110°C) and placing it in a pre-weighed platinum crucible.

a) Heating the sample in a furnace at 1000°C for approximately one hour.

b) Once cooled, the sample was re-weighed.

c) The difference in weight between the pre- and post-ignition measurements was expressed as a percentage, representing the LOI value.

15.11.0 NATURE OF QUALITY CONTROL PROCEDURES ADOPTED

15.11.1 The standard procedure for XRF as per provision made in the proposal for QA/QC has been followed. All the primary samples have been analysed in the Chemical Laboratory of MECL. In order to assess the bias and inaccuracies in analytical determination, one standard, one blank and one repeat sample has been analysed for each number of primary samples.

15.11.2 In order to ensure the accuracy of the analysed samples, few CRMS are used in the analysis. The Certified Reference Material (CRM) was processed under similar conditions as samples and run after every 20 samples, the values of which have been tabulated in the table below. For ICP-MS: NCS DC-73022 (Approved by China National Analysis Centre for Iron and Steel, Beijing, China) has been used as certified reference material. For XRF: GBW07103 and GBW07105

CRM NCS DC-73022 (Approved by China National Analysis Centre for Iron and Steel, Beijing, China).			
Element	**Value**	**Element**	**Value**
Al_2O_3	13.61%	Cr	72 ± 3
CaO	4.32%	Cu	28.2
Fe_2O_3	5.89%	Pb	42.5
K_2O	2.48%	Zn	134
MgO	1.72%	Ni	31.2
Na_2O	1.62%	Co	15.8
P_2O_5	0.16%	Mn	812
SiO_2	61.5%	As	12.4
TiO_2	0.65%	Hg	0.072
LOI	6.35%	Mo	0.7
Ba	412	Nd	40.0
Sr	98	V	89
Zr	156	Sc	13.5

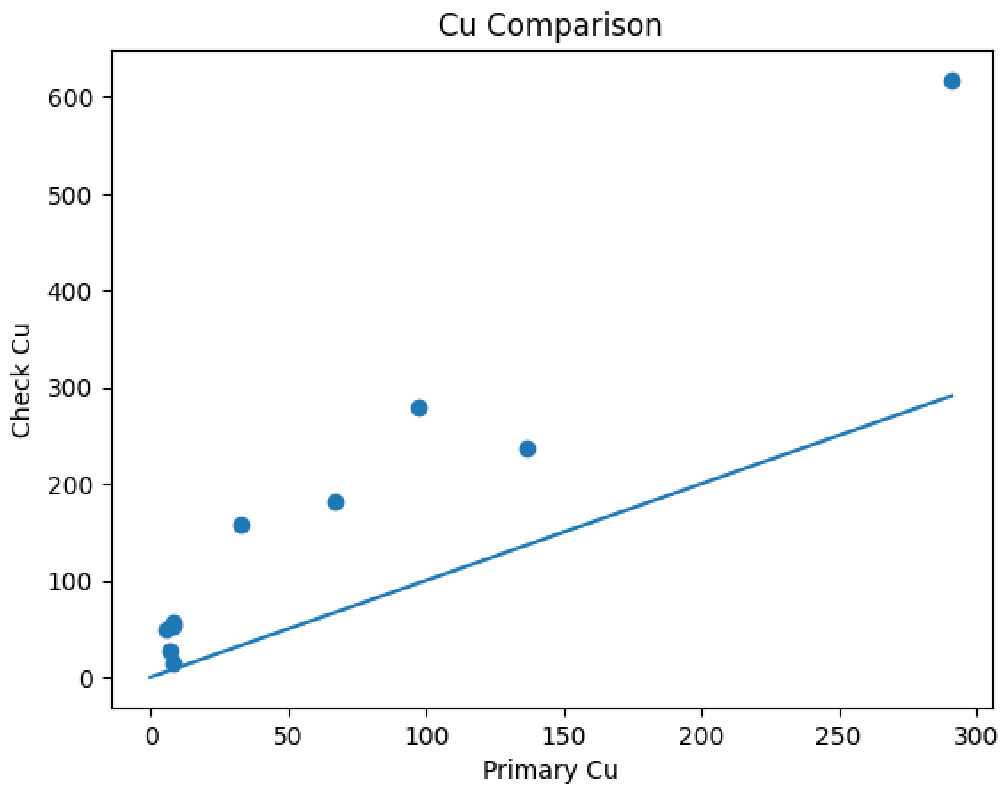
15.12.0 CHECK ANALYSIS FROM THIRD PARTY NABL ACCREDITED LABORETORY

15.12.1 The third-party samples analyses have been carried out at Jawaharlal Nehru Aluminium Research Development and Design Centre, (JNARDDC) Nagpur (A Government Laboratory). A total of 17 numbers of external check samples is analysed for AAS, Fire-Assay, ICP-MS, XRF. The comparative studies of primary vs external check analysis for samples will be attached as Annexure-IX.

15.12.2 **Comparison of Primary Vs External Check Assay Value of Polymetals (Cu-Pb-Zn-Ag & Au and ICP-MS, XRF)**

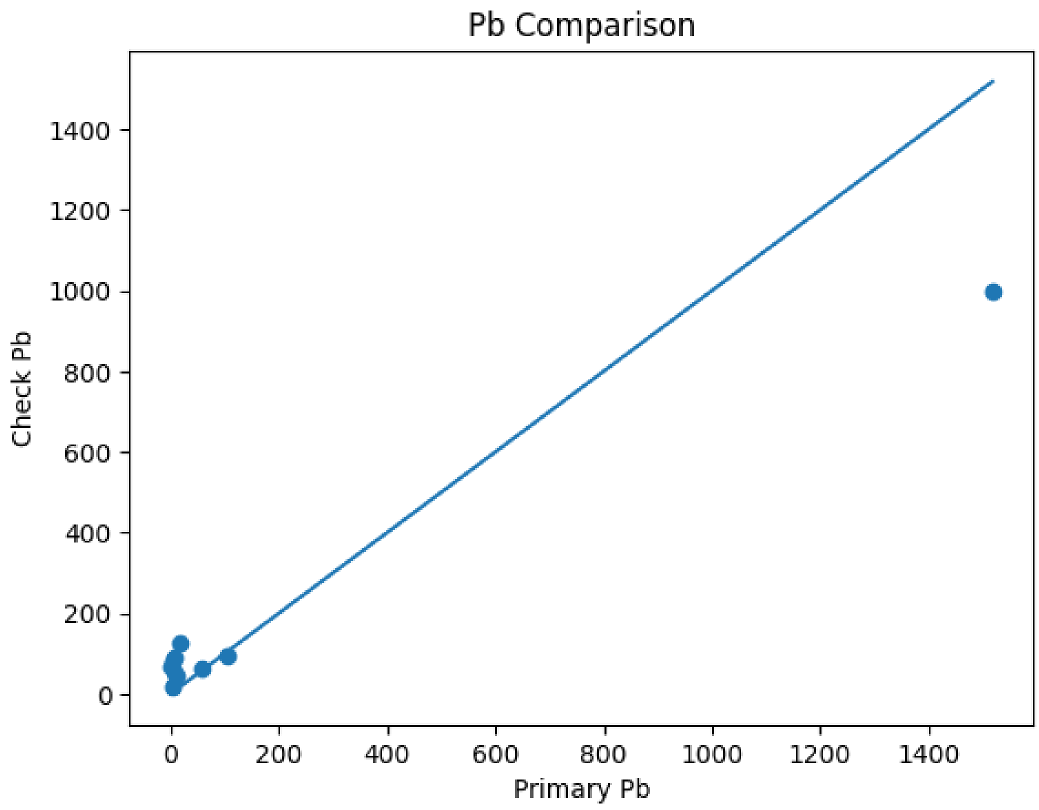
15.12.3 In accordance to the standard practice of quality assurance and quality control, external check samples analysis has been carried out at Jawaharlal Nehru Aluminium Research Development and Design Centre, (JNARDDC) Nagpur (A Government Laboratory). 10% of primary samples, i.e. 17 no. of samples for chemical analysis including, the AAS, Fire-Assay, ICP-MS, XRF have been analysed as external check sample. The comparison charts of all the Analysis are as follows:

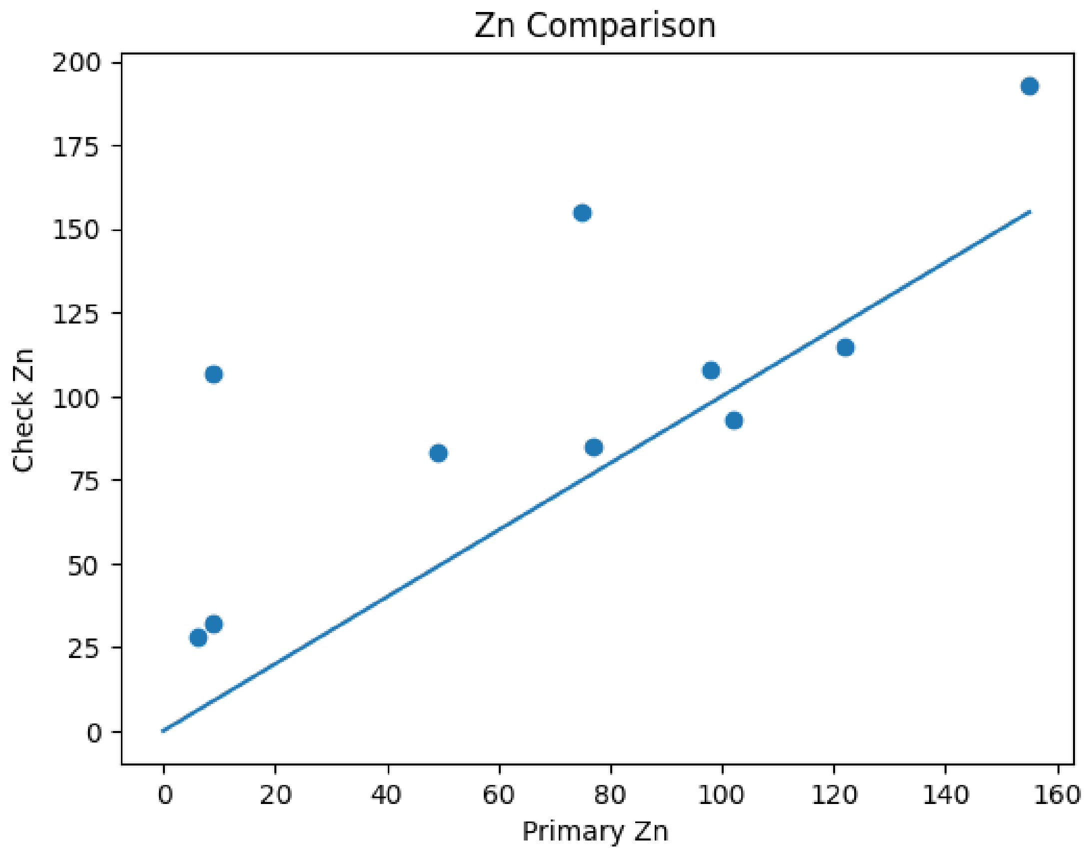
15.12.4 The comparative scatter plot of Cu (Primary vs Check) shows a strong linear correlation with close clustering along the 1:1 reference line, indicating excellent analytical reproducibility and precision. Minor deviations at higher concentrations suggest limited heterogeneity.

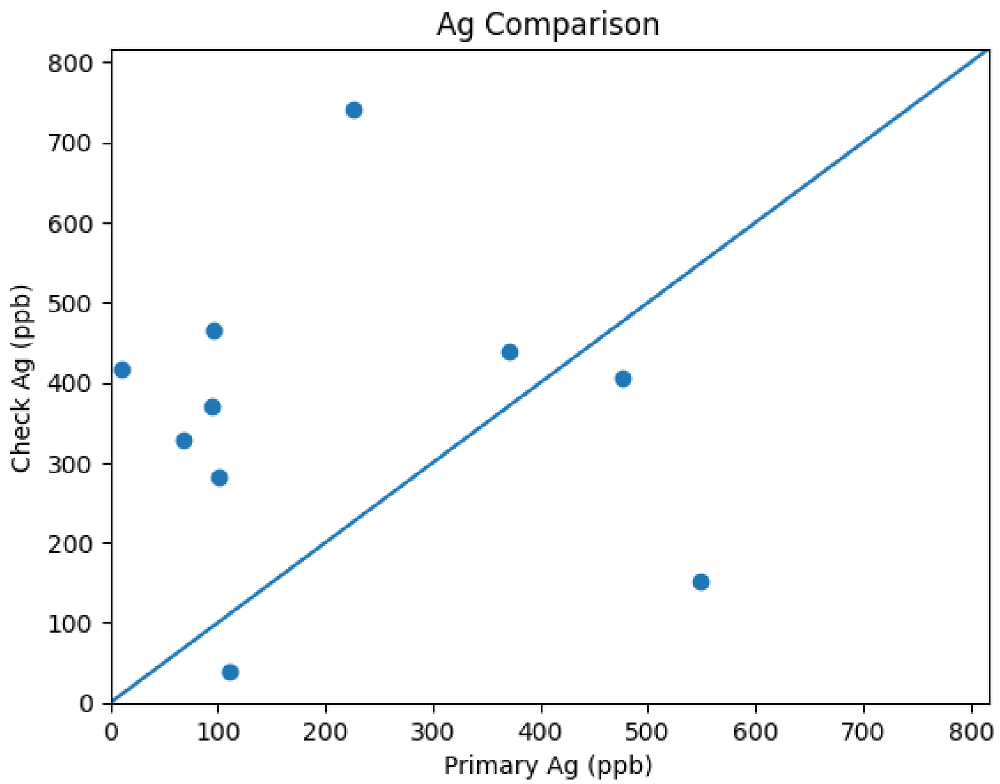


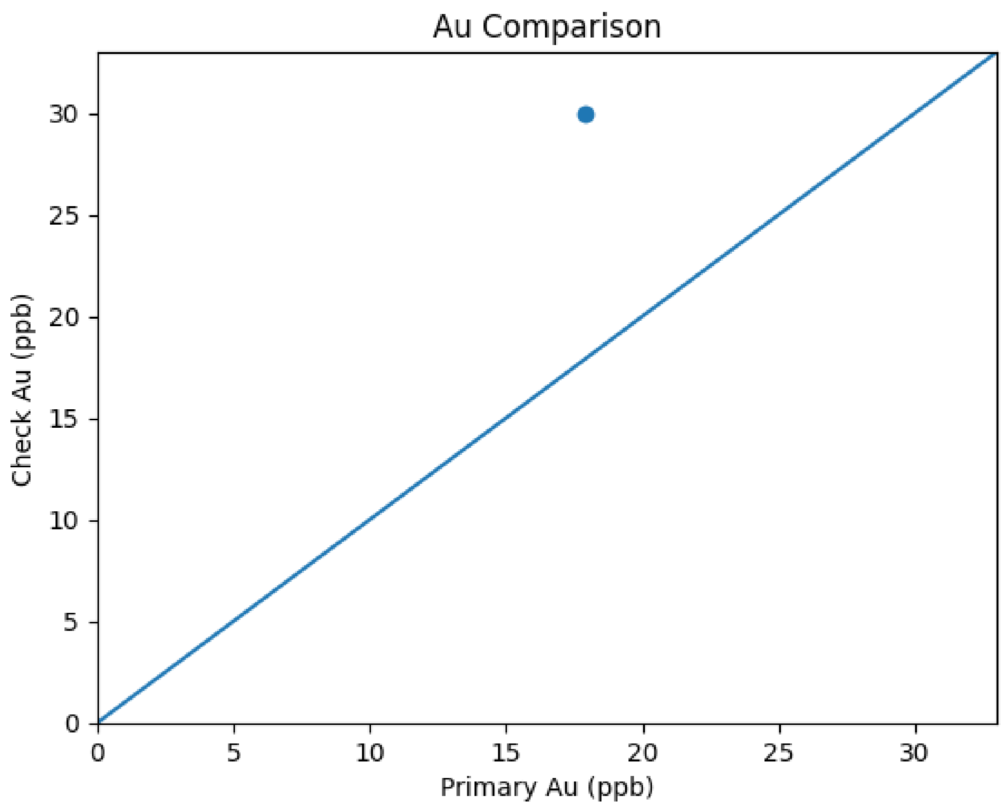
15.12.5 Pb exhibits moderate correlation with noticeable scatter, particularly at higher concentrations. The deviation from the 1:1 line suggests localized enrichment and possible nugget effect, likely due to galena occurring in discrete zones.

15.12.6 Zn shows moderate agreement between primary and check datasets, with some dispersion around the 1:1 line. This reflects partial hydrothermal control and moderate element mobility.


Pb Comparison
1400
1200
1000
800
600
400
200
0
Check Pb
0
200
400
600
800
1000
1200
1400
Primary Pb


Zn Comparison
200
175
150
125
100
75
50
25
0
Check Zn
0
20
40
60
80
100
120
140
160
Primary Zn

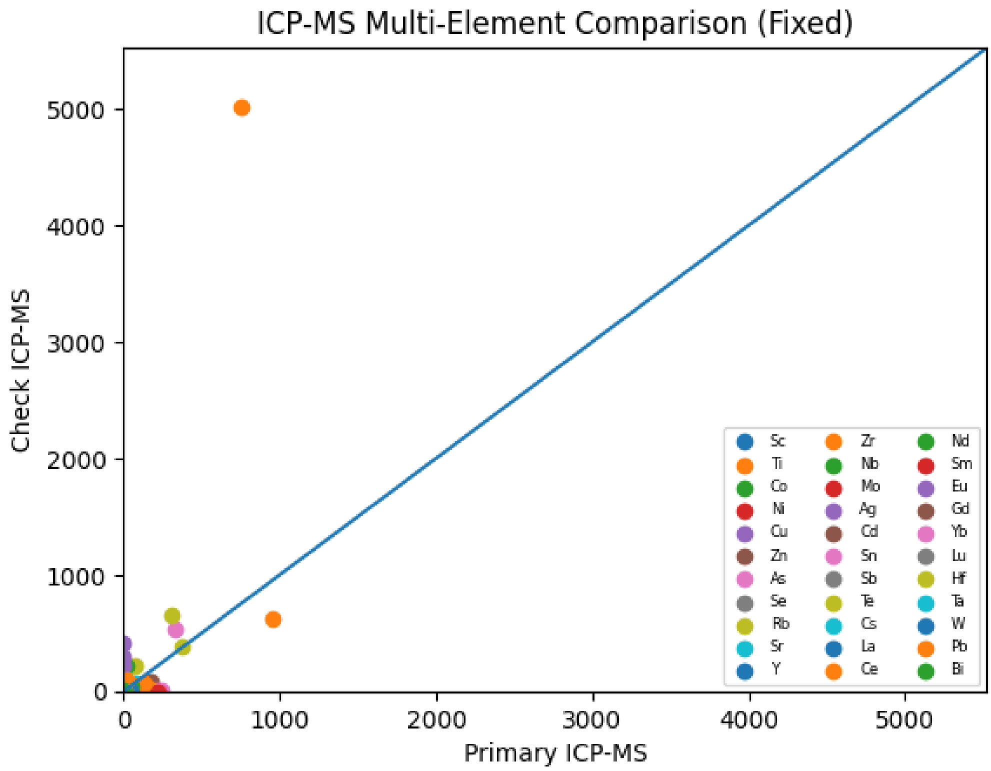




15.12.7 The Ag comparison (corrected to consistent ppb units) shows significant scatter with poor correlation, indicating high variability between primary and check analyses.

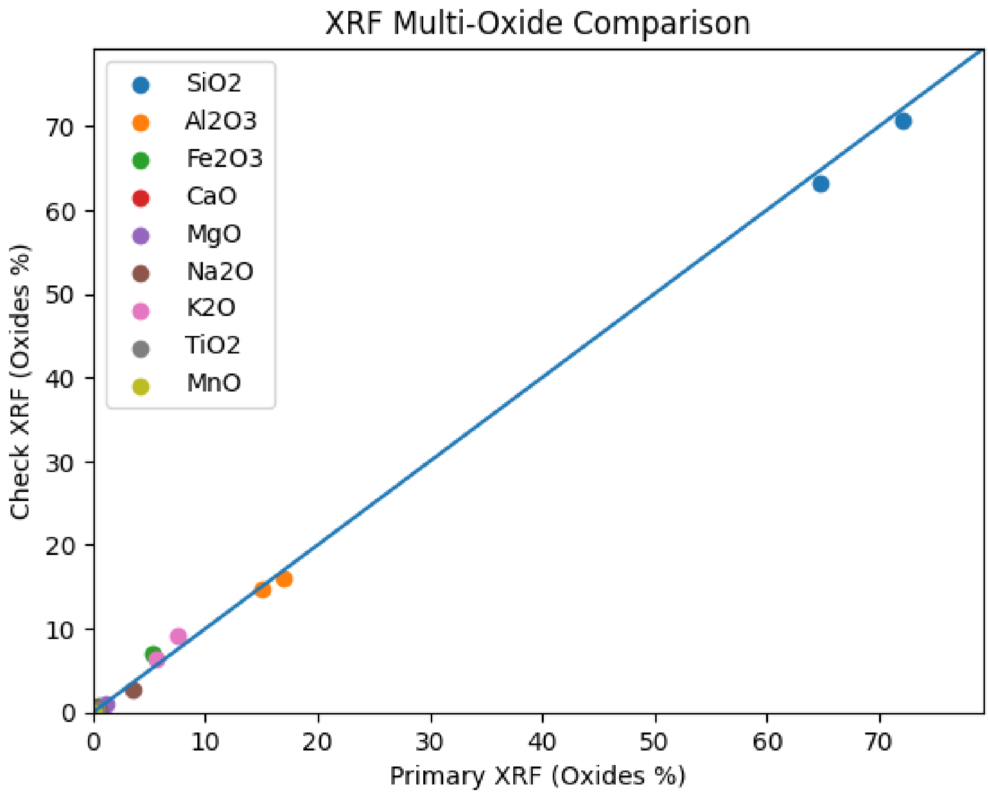
This behavior is attributed to high mobility of Ag in hydrothermal fluids and multi-stage mineralization processes.

15.12.8 The Au comparison plot shows marked deviation from the 1:1 line, with a noticeable difference between primary and check values. This indicates poor repeatability of gold values between splits. Such variability is characteristic of: Low-level concentrations near detection limits, and/or Sample heterogeneity (nugget effect).



15.12.9 The comparative graphs of ICP-MS and XRF major oxide data indicates variation across the two methods. The ICP-MS scatter plot, generated using common elements between primary and check datasets, shows a mixed pattern of agreement, with several elements clustering near the 1:1 reference line at low to moderate concentrations, while others display noticeable dispersion and occasional outliers, reflecting differences in analytical sensitivity, detection limits, and possible sample heterogeneity. This suggests that ICP-MS data is generally acceptable but requires element-wise validation before interpretation. In contrast,

15.12.10 XRF multi-oxide comparison demonstrates excellent agreement between primary and check analyses, with most data points plotting closely along the 1:1 line, indicating high analytical accuracy and reproducibility for major oxides. Minor deviations observed in certain mobile oxides (e.g., Na_2O, K_2O) remain within acceptable limits and are consistent with expected geochemical variability. Overall, while ICP-MS data requires selective use, the XRF dataset is considered robust and reliable for lithogeochemical interpretation.



15.13.0 SECURITY AND CHAIN OF CONTROL OF SAMPLES SHOULD BE CLEARLY MENTIONED

15.13.1 Strict adherence to chain of custody protocols ensured the integrity of the geochemical samples throughout the process, from collection to analysis. A dedicated, centralized mechanized sampling unit handled sample preparation. Qualified sampling technicians oversaw the entire process, ensuring proper labelling and tagging of each sample. Standard procedures were meticulously followed during sample preparation to minimize the risk of contamination. The sampling unit's physical separation from the chemical laboratory further eliminated any potential for cross-contamination. Documentation and Traceability:

15.13.2 A comprehensive chain of custody record was maintained throughout the process. This record documented the movement of each sample from the field to the laboratory, including details such as:

a) Sample identification number

b) Location of Sample

c) Name of sampling personnel

d) Any Specific instruction for crushing

e) Date of Dispatch of Sample

15.13.3 This chain of custody record served as a verifiable audit trail, ensuring the traceability of each sample and upholding the integrity of the collected data. Depending on the specific project requirements, additional security measures could be implemented. These might include tamper-evident seals placed on sample containers, secure storage facilities, and controlled access procedures within the sampling unit and laboratory.

CHAPTER-16

MOISTURE

16.1.0 All the analyses for Cu-Pb-Zn-Ag & Au in rock samples were carried out with natural moisture.

CHAPTER-17

BULK DENSITY

17.1.0 The present exploration was conducted for Cu-Pb-Zn-Ag & Au mineralization in the Amritpur G-4 Block, Nainital, for which bulk density measurements have not been carried out.

CHAPTER-18

BENEFICIATION STUDIES

18.1.0 Given the limited scope of that exploration and, the Cu-Pb-Zn-Ag & Au, and their ore body was not established at the required cutoff grades. Thus, no beneficiation studies were conducted in that block.

CHAPTER-19

RESOURCE ESTIMATION TECHNIQUE

19.1.0 GENERAL

19.1.1 The Reconnaissance Survey (G-4) for Cu-Pb-Zn-Ag & Au in Amritpur was carried out to assess the mineral potential of the area. The exploration was completed by geological mapping of nearly 25.77 sq. km and surface sampling. A comprehensive analysis was conducted on 131 primary samples, encompassing bedrock and Stream Sediments. Based on the analysis of the samples, a few were reported with anomalous values. However, the extension of the ore body was not delineated at the cut-off grade. Thus, with limited values, a resource zone had not been estimated for the block.

CHAPTER-20

REPORTING OF RESOURCES

20.1.0 As discussed in chapter-18, no Polymetals (Cu-Pb-Zn-Ag & Au) ore body has been established at required cutoff grade, hence resource has not been estimated in this block.

20.2.0 The present exploration conducted for Polymetals (Cu-Pb-Zn-Ag & Au) mineralization in the Amritpur G-4 Block, Nainital, for which bulk density measurements have not been carried out

CHAPTER-21

SUMMARY AND RECOMMENDATIONS

21.1.0 SUMMARY

21.1.1 The Amritpur Block forms part of the Lesser Himalayan lithotectonic domain and is characterised by a mixed volcanic–sedimentary lithological assemblage comprising rhyodacite porphyries, ferruginous shales, ferruginous quartz arenites, ferruginous quartzites, altered amphibolites and granitic rocks. These lithological units represent alternating felsic volcanic, sedimentary and subordinate mafic components that collectively form a favourable host environment for hydrothermal mineralisation. The presence of rhyodacitic volcanics, quartz-rich sedimentary rocks and altered mafic units indicates a heterogeneous felsic–mafic volcanic–sedimentary system, which is favourable for hydrothermal fluid circulation and metal deposition.

21.1.2 Structurally, the Amritpur Block lies within a tectonically active sector of the Lesser Himalayan fold-thrust belt, influenced by deformation associated with the Main Boundary Thrust (MBT) and associated local shear zones. These tectonic structures have generated extensive fracture networks, shear zones and structural discontinuities within the rock units. Such structures act as favourable fluid pathways for hydrothermal circulation, resulting in localized mineralisation along fractures, veins, shear-controlled zones and Litho-contacts.

21.1.3 Petrographic studies indicate that rhyodacitic rocks shows porphyritic textures with phenocrysts of plagioclase, quartz and K-feldspar embedded within a fine-grained quartz-feldspathic groundmass. Plagioclase commonly shows intense sericitization, reflecting hydrothermal alteration. Ferruginous quartz arenites and quartzites consist predominantly of quartz grains with ferruginous matrix and disseminated opaque minerals. Altered mafic rocks and amphibolites exhibit mineral assemblages of actinolite–tremolite, epidote, chlorite, sericite and altered plagioclase, indicating significant hydrothermal alteration and metamorphic overprint. The presence of kaolinised feldspars and calcite–chlorite veins in several samples further indicates late-stage hydrothermal activity. Overall, petrographic observations reveal pervasive alteration including sericitization, chloritization, epidotization, kaolinisation and carbonate veining, suggesting extensive fluid–rock interaction.

21.1.4 Mineragraphic studies indicate that the ore mineral assemblage is dominated by pyrite, which occurs as coarse patches, veins and disseminations within host rocks. Minor sulphide minerals such as chalcopyrite, galena and pyrrhotite occur as fine disseminations or fracture fillings. Secondary iron oxides such as hematite, goethite and limonite are commonly present as oxidation products of primary sulphides. Accessory minerals including ilmenite, rutile/anatase and sphene (titanite) occur as fine disseminations. Textural relationships such as chalcopyrite altered to covellite and hematite replacing pyrite suggest supergene alteration processes. These features indicate multi-stage hydrothermal mineralisation associated with structurally controlled fluid pathways.

21.1.5 Geochemical analyses indicate the presence of polymetallic geochemical anomalies characterised by **Cu–Pb–Zn** association with **Ag** and subordinate **Au**. Copper (Cu) values reach up to **>4900 ppm,** lead (Pb) exceeds **1500 ppm**, and zinc (Zn) occurs in the range of **996 ppm**. Silver (Ag) values exceed **2000 ppb**, while gold (Au) noted around **373 ppb**. These anomalies are spatially clustered within the ABLBR and ABLSSS sampling grids, suggesting a strong association with structural zones and hydrothermal alteration domains. The geochemical distribution pattern indicates that mineralisation is structurally controlled and localized along fracture systems and shear zones.

21.1.6 The mineralisation in the Amritpur Block is interpreted as a **structurally controlled hydrothermal polymetallic vein-stockwork system with subordinate orogenic-style Au–Ag enrichment**. Sulphide minerals occur as disseminations, fracture fillings, veins and stockwork networks within altered volcanic and sedimentary host rocks. Hydrothermal alteration assemblages dominated by **quartz–sericite–chlorite ± epidote–carbonate** are widely developed around the mineralised zones, indicating epizonal to mesozonal hydrothermal conditions. The mineralisation appears to be spatially associated with fracture systems and shear zones related to the regional tectonic framework and the Main Boundary Thrust, which likely acted as conduits for ascending metal-bearing fluids. The overall geological, mineralogical and geochemical characteristics suggest that the Amritpur Block hosts a **hydrothermal polymetallic vein-stockwork system comparable to orogenic polymetallic deposits**, rather than stratabound VMS or SEDEX styles.

21.2.0 RECOMMENDATIONS

21.2.1 Based on the geological mapping, petrographic and mineragraphic studies, and geochemical data, the Amritpur Block exhibits encouraging indications of **structurally controlled hydrothermal polymetallic mineralisation** characterised by Cu–Pb–Zn–Ag with subordinate Au. The mineralisation is closely associated with **hydrothermal alteration zones and structurally controlled fracture networks**, indicating the importance of structural pathways in controlling fluid flow and metal deposition.

21.2.2 In view of these observations, it is recommended that detailed geological mapping and structural analysis be undertaken to further delineate the distribution of lithological units, hydrothermal alteration zones and fracture-controlled mineralised trends. Particular attention should be given to the orientation and continuity of shear zones, fractures and vein systems that may have acted as conduits for mineralising fluids. Systematic bedrock and channel sampling across the exposed outcrops may also be carried out to refine the geochemical anomaly patterns and to better understand the spatial distribution of polymetallic mineralisation.

21.2.3 As the mineralised outcrops are already well exposed in the study area, trenching is not considered necessary. Instead, the exposed mineralised zones provide an excellent opportunity for direct surface evaluation and sampling. However, to assess the Quartz vein continuity, and thickness, further close grid sampling and few scout boreholes are recommended. Few drill holes across the identified zones and geochemical anomalies would help in determining the vertical persistence of sulphide mineralisation, identifying potential feeder structures and evaluating the source of the hydrothermal fluids responsible for the observed polymetallic enrichment.

21.2.4 Further analytical studies, including detailed mineralogical and geochemical investigations, may also be undertaken to better understand the paragenesis and evolution of the mineralising system. Such integrated investigations will help establish a comprehensive genetic model for the mineralisation and assist in identifying the most prospective zones for further exploration.

21.2.5 Overall, the presence of hydrothermal alteration, structurally controlled sulphide mineralisation and significant polymetallic geochemical anomalies indicates that the Amritpur Block holds promising potential for polymetallic mineralisation. Therefore, the block warrants systematic advanced exploration, to evaluate the economic significance and subsurface extent of the mineralised system.

CHAPTER-22

PLATES AND MAPS

22.1.0 Location Map of the block showing various topographic and physiographic features nearby the Amritpur block is given as Plate-I.

22.1.1 Regional Geology Map on 1:50,000 scale is given as Plate-II.

22.1.2 Block Geological Map on 1:12,500 scale is given as Plate- III.

22.1.4 Sample Location with Polymetals (Cu-Pb-Zn-Ag & Au) distribution on Geological Map given as Plate-IV.

22.1.5 Sample Location with DEM of the area given as Plate-V

22.1.6 Stream Sediment sample anomaly map of the area for Cu given as Plate-VI-A

22.1.7 Bed rock anomaly map of the area for Cu given as Plate-VI-B

CHAPTER-23

ANNEXURE / ENCLOSURES TO THE REPORT

23.1.0 The report includes all the relevant annexure and maps, plans, sections, photographs & photomicrograph etc. List of annexures, tables, maps/plans/sections, photographs, Text figures & photomicrograph etc. are provided before the start of the Text part of the Geological Report.

CHAPTER-24

ANY OTHER INFORMATION

24.1.0 There is no additional information available in the block.

CHAPTER-25

CERTIFICATE FROM THE QUALIFIED PERSON WITH NAME, DATE AND SIGNATURE

This is to certify that geological report has been prepared in respect of Reconnaissance Survey (G-4) for Polymetals (Cu-Pb-Zn-Ag & Au) in Amritpur Area, District Nainital, State: Uttarakhand. The report was produced by Mineral Exploration and Consultancy Limited (MECL) on behalf of the National Mineral Exploration and Development Trust (NMEDT). The report adheres to the Minerals (Evidence of Mineral Contents) Rules, 2015, as specified under the Mineral Auction Rules, 2015, and amended up to 2021.

NAME: **SHRIKANT SHARMA**
DESIGNATION: **HoD (EXPLORATION/NEM)**
DATE: 31-03-2026

LOCALITY INDEX

LOCALITY	LATITUDE	LONGITUDE	ELEVATION (m)
Salri	29°18’45” N	79°33’46” E	814
Amiya	29°17’50” N	79°35’33” E	707
Amritpur	29°17’44” N	79°33’29” E	592
Ranibagh	29°17’14” N	79°32’53” E	600
Basuli	29°17’53” N	79°34’05” E	587
Kharki	29°18’33” N	79°34’32” E	1260
Banana	29°18’22” N	79°37’48” E	1,351
Pinshela	29°18’01” N	79°38’55” E	1,004

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ABBREVIATIONS USED

SL. No.	Abbreviation	Full form
1	UNFC	United Nation Framework Classification
2	NMI	National Mineral Inventory
3	IBM	Indian Bureau of Mines
4	DGCO	Directorate General Camp Office
5	GSI	Geological Survey of India
6	MECL	Mineral Exploration and Consultancy Limited
7	CPSE	Central Public Sector Enterprises
8	NMEDT	National Mineral Exploration and Development Trust
9	TCC	Technical cum Cost Committee
10	EC	Executive Committee
11	DMG, UP	Directorate of Geology & Mining, Uttar Pradesh
12	NABL	National Accreditation Board for Testing and Calibration Laboratories
13	JNARDDC	Jawaharlal Nehru Aluminium Research Development and Design Centre
15	MEMC	Minerals (Evidence of Mineral Contents)
16	MMDR	Mines & Minerals (Development and Regulation)
17	NH	National Highway
18	WGS-84	World Geodetic System-84
19	UTM	Universal Transverse Mercator
20	RL	Reduced Level
21	cu m	Cubic Meter
22	ICP-MS	Inductively Coupled Plasma Mass Spectrometry
23	DGPS	Differential Global Positioning System
24	DMS	Degree Minute Second
25	M / m	Meter
26	mt	Million Tonne
27	Sq. km	Square Kilometer
28	M. Sc.	Master of Science
29	M. Sc. Tech	Master of Science Technology
30	NDDP	Net District Domestic Product
31	mRL	Reduced Level in metre
32	R.F.	Reserve Forest
33	P.F.	Protected Forest
34	QA/QC	Quality Assessment/ Quality Checks
35	WD-XRF	Wavelength Dispersive X-ray Fluorescence
36	CRM	Certified Reference Material
37	SARM	South African Reference Material
38	ICP-OES	Inductively Coupled Plasma Optical Emission spectroscopy
39	XRD	X-Ray Diffraction
40	ML	Mining Lease
41	NGCM	National Geochemical Mapping
42	NGPM	National Geophysical Mapping
43	AMSE	Airborne Mineral Surveys and Exploration