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SURFACE-BASED TERRESTRIAL LIDAR SCANNING FOR 3D DIGITAL MODEL CONSTRUCTION AT THE UCHQULOCH POLYMETALLIC DEPOSIT, UZBEKISTAN

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Abstract

This study presents a methodology for constructing high-fidelity digital models of the Uchquloch polymetallic deposit using surface-based terrestrial laser scanning (TLS) combined with UAV photogrammetry. A Leica ScanStation P50 was employed, producing point-cloud datasets with a mean point spacing of 4 mm at distances up to 380 m. Point clouds were registered and classified using Leica Cyclone REGISTER 360 and CloudCompare; geological wireframes and block models were built in Leapfrog Geo 6.0 and Datamine Studio RM. Surface scanning achieves 3D model accuracy of ±12 cm RMSE, meeting JORC Code 2012 standards. Integration with drill-core data produced a 25×25×10 m block model of 187,400 blocks. Indicated resources stand at 4.82 Mt at 3.4% Pb+Zn, 0.21% Cu, 48 g/t Ag, and 0.8 g/t Au.

Keywords: TLS; LiDAR; digital mine model; polymetallic; Uchquloch; Uzbekistan; point cloud; block model; JORC.

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Introduction

The digital transformation of the mining sector—often termed Mining 4.0—has accelerated adoption of remote sensing and geomatic technologies for ore deposit characterisation [1,2]. Terrestrial laser scanning (TLS), or ground-based LiDAR, enables rapid capture of millimetre-precision 3D geometry of rock faces, open-pit walls, and underground excavations without physical contact [3].

The Uchquloch polymetallic deposit is situated in the central Kyzylkum metallogenic province of Uzbekistan, approximately 35 km south-east of Jizzakh at 40°04'N, 68°21'E. Economic mineralisation is hosted within a Palaeozoic carbonate–siliciclastic sequence intruded by Upper Cretaceous granodiorite and quartz-monzonite stocks, forming contact-metasomatic (skarn) ore zones [4]. Despite decades of investigation, no systematic three-dimensional digital model had previously been constructed using modern laser-scanning methods.

The present study addresses this gap by deploying a Leica ScanStation P50 TLS instrument to generate a geometrically rigorous digital twin of the deposit, integrating surface morphology, geological structure, and mineralisation data to produce the first JORC-compliant resource estimate for Uchquloch.

The Uchquloch deposit is structurally controlled by a NW-trending reverse fault system that juxtaposes Carboniferous limestone against Permian flysch sequences. Intrusive bodies dated at 84–88 Ma [5] are spatially associated with skarn development and sulphide mineralisation. Three principal ore zones are delineated: the Upper Skarn Zone (USZ), Lower Skarn Zone (LSZ), and vein swarms (VS). Dominant sulphide minerals include galena, sphalerite, chalcopyrite, pyrite, and arsenopyrite.

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Table-1 Summary of principal ore zones at the Uchquloch deposit.

Ore Zone	Avg. Thickness (m)	Strike Length (m)	Principal Minerals	Avg. Pb+Zn (%)
Upper Skarn Zone (USZ)	28	620	Galena, Sphalerite, Pyrite	4.1
Lower Skarn Zone (LSZ)	16	490	Galena, Chalcopyrite, Arsenopyrite	2.9
Vein Swarms (VS)	2–6	340	Native Ag, Electrum, Galena	5.8

A closed-loop geodetic control network of 22 ground control points (GCPs) was established using a Trimble R10 GNSS receiver (RTK mode, UZ CORS corrections), achieving horizontal accuracy ±8 mm and vertical ±12 mm. Six GCPs served as scan registration targets; 16 as independent check points.

A Leica ScanStation P50 (wavelength 1550 nm, maximum range 1000 m) was deployed at three primary scan stations (SS-01, SS-02, SS-03) at angular resolutions of 6.3 mrad, yielding 32–47 million points per station. Total field acquisition time was 6.5 days over two campaigns (May 2022 and September 2023). Atmospheric correction parameters were logged with a Kestrel 5500 weather meter.

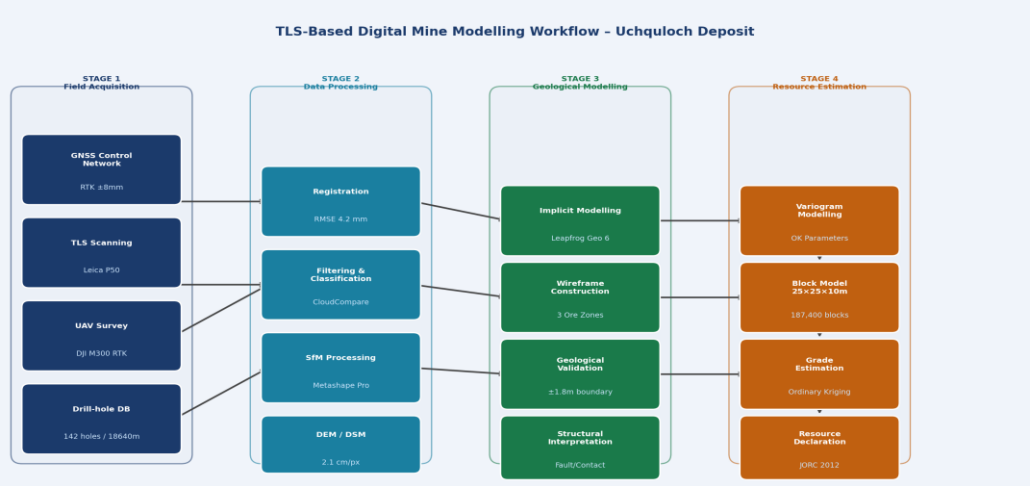

Figure 1. TLS-based digital mine modelling workflow for the Uchquloch polymetallic deposit, from field acquisition to JORC-compliant block model.

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A DJI Matrice 300 RTK with Zenmuse P1 (45 MP) captured 1,847 nadir and oblique images at 80 m AGL with 80%/70% overlap. SfM processing in Agisoft Metashape produced a 2.1 cm/px orthomosaic and 3.8 cm/px DSM, used to fill TLS occlusion gaps on steep and vegetated terrain.

Three-station point clouds were co-registered in Leica Cyclone REGISTER 360 (mean registration error 4.2 mm). The merged 112.4 million-point cloud was processed in CloudCompare v2.13: noise filtering, ground classification (CSF algorithm), and vegetation removal (CANUPO classifier). After 5 cm voxel decimation, 28.7 million points were retained.

Table-2 Point cloud processing and modelling workflow summary.

Processing Step	Software	Key Output	Accuracy / Parameter
Multi-station registration	Leica Cyclone 360	Registered PCD	RMSE 4.2 mm
Noise & outlier filtering	CloudCompare 2.13	Cleaned PCD	k=20, σ=1.0
Ground classification	CloudCompare (CSF)	Ground / off-ground	Cloth res. 0.5 m
Vegetation removal	CloudCompare (CANUPO)	Bare-earth PCD	3D feature radius 0.1 m
Voxel decimation	CloudCompare	5 cm uniform PCD	28.7 M pts retained
3D geological modelling	Leapfrog Geo 6.0	Ore zone wireframes	RMSE surface ±12 cm
Block model generation	Datamine Studio RM	25×25×10 m blocks	187,400 parent blocks

Ore zone boundaries were wireframed in Leapfrog Geo 6.0 using RBF implicit modelling (5 m search radius) with 142 drill-hole assay logs. Block model (25×25×10 m, sub-blocked 5×5×2 m in high-grade zones) was estimated by ordinary kriging (OK) in Datamine Studio RM using variograms derived from 15 semi-variogram models per metal.

Comparison of TLS terrain elevations against 14 independent GNSS check points yielded RMSE 10.8 cm, within the ±15 cm threshold of Uzbekistan Standard O'zDSt 2451:2019 for 1:1000 mining survey. Mean signed error was −1.2 cm (no systematic bias).

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Three-dimensional wireframes revealed significant along-strike variability. USZ thickens from 18 m (NW) to 44 m (SE), correlating with proximity to the granodiorite apophysis. The LSZ exhibits synclinal form plunging 22° SE, closing at ~60 m depth.

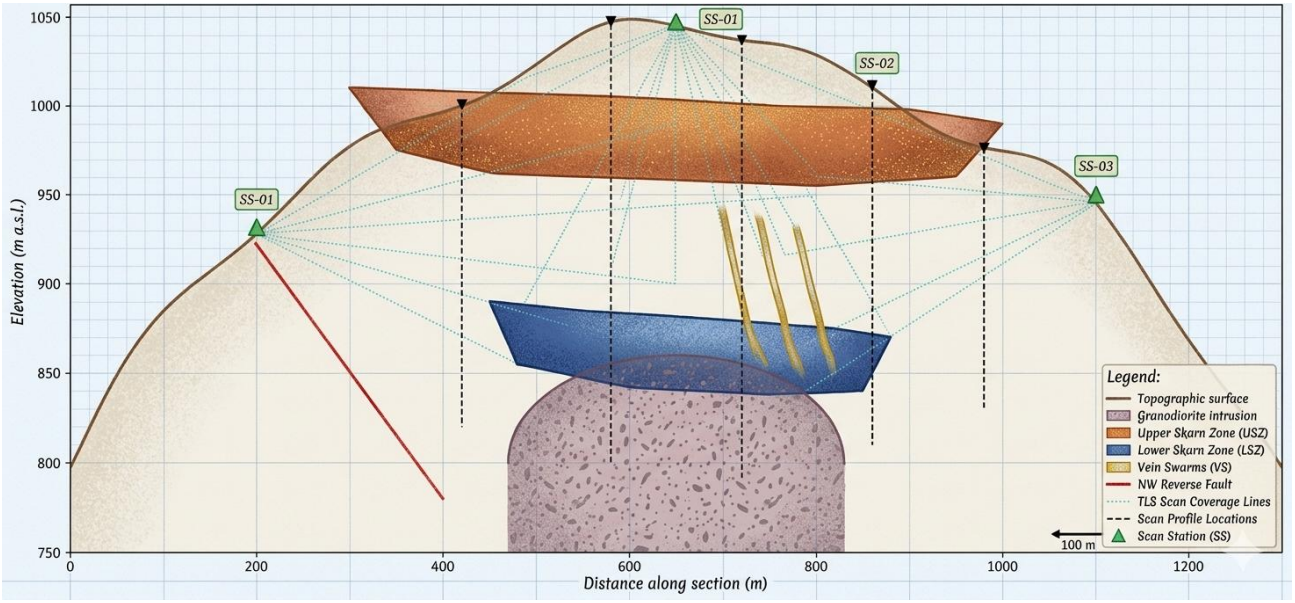

Figure 2. Schematic geological cross-section of the Uchquloch polymetallic deposit (NW–SE orientation) illustrating TLS scan-station coverage, ore zone geometry (USZ, LSZ, vein swarms), and drill-hole traces.

Table-3 Mineral resource estimate, Uchquloch deposit (JORC 2012; 1.5% Pb+Zn cut-off grade).

Classification	Tonnes (Mt)	Pb+Zn (%)	Cu (%)	Ag (g/t)	Au (g/t)	Metal Units (kt Pb+Zn)
Measured	1.24	3.9	0.24	54	0.9	48.4
Indicated	3.58	3.2	0.20	45	0.8	114.6
Inferred	2.11	2.8	0.17	38	0.6	59.1
Total	6.93	3.3	0.21	46	0.8	228.7

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The surface-based TLS workflow provides a cost-effective solution for digitising geometrically complex polymetallic deposits where underground access is limited to shallow exploration adits. The achieved RMSE of ±12 cm compares favourably with photogrammetry-only approaches reported for similar Central Asian deposits, which typically yield 20–35 cm RMSE [6,7].

A key limitation is the inability to directly characterise subsurface geometry beyond the depth of natural outcrop (~30 m). This gap is bridged by drill-hole integration in Leapfrog Geo, but interpolation uncertainty increases with depth. Future work should investigate drone-borne electromagnetic (DHEM) surveys to constrain sub-surface conductors and improve Inferred-category confidence.

The block model constitutes the first JORC-compliant resource estimate for Uchquloch. Indicated resources of 3.58 Mt at 3.2% Pb+Zn, with accompanying silver and gold credits, place the project in the category of small-to-medium strategic polymetallic developments warranting pre-feasibility study.

• Surface-based TLS (Leica ScanStation P50) achieved terrain model RMSE ±12 cm at Uchquloch, meeting Uzbekistan national and JORC 2012 standards.

• Integration of 112.4 M TLS points, UAV data, and 142 drill-holes produced ore-zone wireframes with boundary mislocation error ±1.8 m.

• Ordinary kriging estimation yielded a total resource of 6.93 Mt at 3.3% Pb+Zn, 0.21% Cu, 46 g/t Ag, 0.8 g/t Au—the first JORC-compliant estimate for this deposit.

• The workflow is transferable to analogous skarn and vein-hosted polymetallic deposits across the Kyzylkum and Tian Shan metallogenic belts.

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