# Susitna-Watana Hydroelectric Project Document
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SUSITNA-WATANA HYDRO

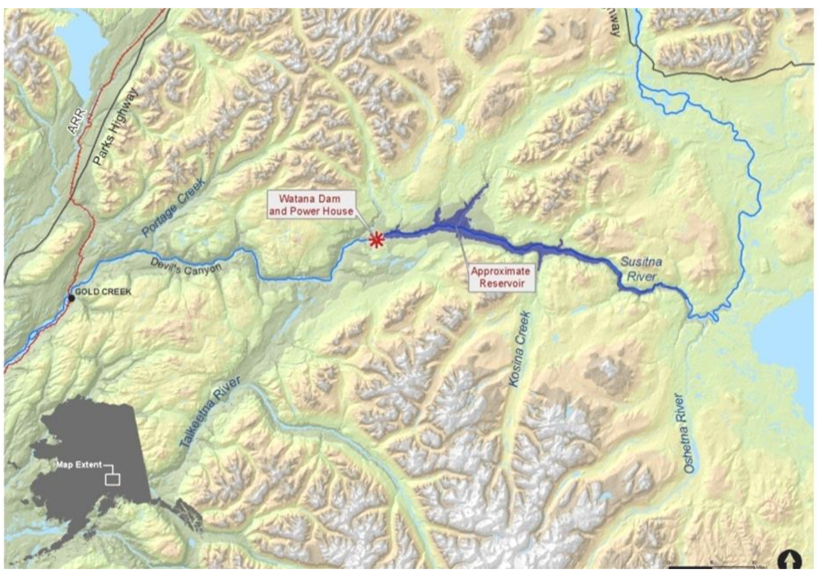
# ATTACHMENT 6: REGIONAL GEOLOGIC ANALYSIS

SUSITNA-WATANA
HYDROELECTRIC PROJECT

**NTP 11**
**Technical Memorandum No. 9**
**V0.0**

# REGIONAL GEOLOGIC ANALYSIS

**AEA11-022**

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# 1.0 INTRODUCTION

The initial feasibility study for the Susitna Hydroelectric Project in 1981 produced terrain unit maps of the proposed Devil Canyon and Watana dam site areas, reservoir areas, construction material borrow areas, and access and transmission line corridors (Acres, 1981). These maps were the product of the interpretations of aerial photographs, terrain unit analysis, and field reconnaissance encompassing approximately 100 square miles. The general objective of the current effort was to review and update this 1981 terrain unit mapping using more advanced aerial imagery.

The terrain unit analysis provides a databank upon which interpretations concerning geomorphologic development, glacial history, and geologic history could be based. It can be used as a base map for the compilation and presentation of various other activities and facilities that are a part of the Susitna-Watana Hydroelectric Project.

Landforms are elements of the landscape with a definable composition and range of physical and visual characteristics resulting from geomorphic origin or mode of deposition. A terrain unit is a special purpose term comprising landforms expected to occur from the ground surface to a depth of about 25 feet. Compound terrain units describe surficial landforms, but also an interpretation of the underlying landform when the underlying material is within about 25 feet of the surface. Complex terrain units have been mapped where the surficial exposure pattern of two landforms are so intricately related that they must be mapped as a terrain unit complex, such as some areas of bedrock and colluvium (Acres, 1981). The rationale for using terrain units is that similar geologic processes tend to result in landforms with similar environmental and geotechnical properties that present similar engineering problems. The landform classification used in the original terrain unit mapping for this project was developed during the Trans Alaska Pipeline geotechnical investigations and was based on a considerable amount of laboratory testing data (Kreig and Reger, 1982).

Terrain unit mapping for this project is a cost-effective means to generate and compile baseline geologic information for a large area that has had little prior investigation other than previous subsurface studies in the vicinity of the proposed dam. The general objective of the original mapping was to document geological features and geotechnical conditions that would affect the design and construction of the project features. This included the delineation of terrain units of various geomorphic origins on aerial photographs noting the occurrence and distribution of geologic factors such as permafrost, potentially unstable slopes, bearing potential, potentially erodible soils, frost heave potential, thaw settlement potential, and suitability as a borrow source. Physical property observations and interpretations for the delineated areas allow assessment of each terrain unit's influence on project features.

The maps have been primarily developed through image interpretation and limited on-the-ground field checking and are therefore not intended as a definitive representation of actual subsurface conditions. The engineering characteristics of these units have been generalized and described qualitatively. The boundaries of terrain units should be considered to be approximate. While the terrain unit mapping is a useful tool for understanding general subsurface conditions, it does not negate the need for site specific investigations for future applications as the project progresses.

## 2.0 SCOPE AND METHODOLOGY

A regional geologic analysis was conducted in 2012 to update the 1981 regional terrain unit maps for the areas relevant to the Susitna-Watana Hydroelectric Project. The scope of this update included the interpretation of recently acquired LiDAR (Light Detection and Ranging) and IFSAR (Interferometric Synthetic Aperture Radar) imagery and color aerial photographs. It also included two days of field inspection via helicopter by two geologists. The mapping was limited by the extent of the high resolution LiDAR coverage and the relatively lower-resolution IFSAR imagery that covered the 1981 mapping area. Despite the relatively lower resolution of IFSAR imagery compared to LiDAR, the IFSAR data still represents an improvement over the resolution of the prior base for the terrain unit mapping. The field inspection included a general fly-over with spot checks on the ground to inspect slide areas, photograph specific features, sample landslide deposits, and to probe the depth of organic deposits. Photographs of examples of each terrain unit are presented in Appendix A.

This current mapping effort began with the review of the 1981 mapping (Acres, 1981), and relevant geologic information published by Alaska and federal government agencies (Csejtey and others, 1978; Williams, 1986; Kreig and Reger, 1982; Woodward Clyde Consultants, 1982; Leonard and Kargel, 2010; Jorgenson and others, 2008). It also consisted of rubber-sheeting scans of the 1981 terrain unit maps into the project coordinate system, digitizing and attributing the existing terrain unit polygons, and overlaying the polygons on the new LiDAR and IFSAR data sets. The modeling of the LiDAR data in "bare earth" mode produced 3D imagery of the ground surface with the vegetation removed. This allowed a finer level of accuracy for delineation of terrain units and revealed surface features not discernible by interpretation of aerial photography alone. Because the original mapping was done on a relatively broad scale and without geo-rectified photography, the polygons for the terrain units were moved and adjusted to correspond to their correct location in the geo-rectified GIS format. This new digital format allows the user to add new layers and readily make other changes as new data becomes available.

The nomenclature and engineering characteristics for the original terrain unit maps has not been significantly changed except for the addition of a new terrain unit to represent inactive landslides (Map Symbol - Cli) to distinguish them from active landslides (Map Symbol - Cl). The legend was simplified by removing the descriptions of compound and complex terrain units. This was deemed to be justified since the individual terrain units comprising compound and complex terrain units are described. Slide scarps, which indicate relatively recent slope failure, are shown as lines following the scarp trace with arrows indicating the direction of movement.

## 3.0 GEOLOGIC SETTING AND QUATERNARY GLACIATION

The Susitna-Watana region is a relatively low area in the northern portion of the Talkeetna Mountains which separates the Copper River Basin to the east from the Susitna Cook Inlet Basin to the west. The area is underlain by a variety of rock units consisting primarily of Cretaceous and Tertiary plutonic and volcanic rocks plus argillaceous and lithic greywacke resulting from the accretion of northwestward drifting tectonic plates onto the North American plate (Csejtey, 1978). The region was subjected to repeated glaciation during the late Quaternary. At its glacial maximum, an ice cap covered the Talkeetna Mountains and nearly everything from the crest of the Alaska Range to the Gulf of Alaska. Subsequent advances were not extensive enough to create an ice cap over the Talkeetna Mountains and evidence suggests a series of glaciations of sequentially decreasing extent (Woodward Clyde Consultants, 1982).

The glaciers advanced from the Alaska Range to the north, the southern and southeastern Talkeetna Mountains, and the Talkeetna Mountains north and northwest of the Susitna River. Glacial flow was predominantly south and southwest, following the regional slope and structural grain. Multi-directional and convergent flow, differing glacial magnitudes, topographic influences, and other parameters make the glacial chronology of the project region complex. The more recent glaciations produced the glacially-derived sediments that mantle much of the terrain today. These deposits include glacial, glaciofluvial, and glaciolacustrine sediments (Woodward Clyde Consultants, 1982). Glacio-lacustrine deposits that are widespread in the Susitna-Watana region were laid down during a period of ice-damming of the Copper River in the late-Wisconsin creating ancient Lake Ahtna, a portion of which extended westward over the project area. Ice-damming of the Susitna and Talkeetna Rivers acted to prevent drainage down the present channels of these rivers (Leonard and

Kargel, 2010; Williams and Galloway, 1986). Widespread glaciation of the area ended in the Holocene as the glaciers retreated to the upper reaches of tributary valleys of the Susitna River and drainage was established down the present canyon through rapid down-cutting.

Permafrost distribution in the greater Susitna-Watana region has been characterized as "discontinuous" (50-90 percent of the area is underlain by permafrost) except along the immediate river corridor itself, which is characterized as "isolated" (>0-10 percent of the area is underlain by permafrost) (Jorgenson et. al, 2008). Based on the subsurface investigations to date, most of which are within two miles of the proposed dam site, permafrost is generally continuous (greater than 90 percent of the area is underlain by permafrost) under north-facing slopes. The frozen ground is typically encountered within 10 feet of the surface and extends to depths of approximately 200 feet. Ground temperatures typically range from 31-32°F. Permafrost has typically been absent directly under the river channel and south-facing slopes under the right abutment, although permafrost was encountered in one borehole downstream of the dam. Gentle south-facing slopes in upland areas above the canyon on the north side of the river have been investigated with numerous boreholes in the wider vicinity of the dam. These investigations typically encountered unfrozen ground although sporadic permafrost was present in very localized zones (Acres, 1982). This evidence suggests that the presence of permafrost is sensitive to sun angle.

The proposed reservoir extends approximately 36 miles east of the dam. The geology is complex, generally consisting of variable thicknesses of late Quaternary glacial till, lacustrine deposits, colluvium, outwash and alluvium overlying igneous and metamorphic bedrock. Bedrock is exposed along much of the main channel confining deep deposits of coarse alluvium. Basal till and lacustrine deposits predominate in the uplands above the bedrock along significant portions of the river.

While the proposed reservoir is generally narrow, it is widest where it extends to the northeast up Watana Creek, a tributary to the Susitna River. The slopes along the north side of the Susitna River and Watana Creek are characterized by numerous landslide areas which appear to be the result of the thawing of ice-rich permafrost in the basal till. Where lacustrine deposits overlie the basal till, the lacustrine deposits are undermined when the basal till thaws and fails resulting in slide debris that incorporate both units. The head scarps from these failures are typified by near-vertical slopes in the capping lacustrine deposits and significantly lower-angled slopes in the basal till. The most active slide areas typically have wet surface soils indicating the thawing of excess ice in the basal till.

## 4.0 TERRAIN UNIT DESCRIPTIONS

The soil types and mode of deposition for the 15 landforms (or individual terrain units) are described below. Several of the landforms have not been mapped independently but rather as compound or complex terrain units. The compound and complex terrain units behave and are described as a composite of the individual landforms comprising them.

O – Organic Deposits: Deposits of humus, muck and peat generally occurring in bogs, fens and muskegs.

C – Colluvial Deposits: Deposits of widely varying composition that have been moved downslope chiefly by gravity. Fluvial slopewash deposits are usually intermixed with colluvial deposits.

Cl – Active Landslide: A lobe or tongue-shaped deposit of rock rubble or unconsolidated debris that has recently moved downslope. Landslides include rock and debris slides, slump blocks, earth flows and debris flows. Surface vegetation is absent, sparse, or highly-disturbed.

Cl-i – Inactive Landslide: A lobe or tongue-shaped deposit of rock rubble or unconsolidated debris that has moved downslope and appears to have stabilized. The surface is forested with relatively straight trees.

Cs – Solifluction Deposits: Solifluction deposits are formed by frost creep and the slow, down-slope, viscous flow of saturated soil material and rock debris in the active layer. This unit is generally used only where obvious solifluction lobes are identifiable. It includes fine-grained colluvial fans formed where solifluction deposits emerge from a confined channel on a hillside onto a level plain or valley.

Ffg - Granular Alluvial Fan: A gently sloping cone generally composed of granular material with varying amounts of silt deposited upon a plain by a stream where it issues from a narrow valley. The primary depositional agent is running water. These deposits can include varying proportions of avalanche or mudflow deposits, especially in mountainous regions.

Fp – Floodplain: Deposits laid down by a river or stream and flooded during periods of highest water in the present stream regimen. Floodplains are composed of two major types of alluvium: 1) generally granular riverbed (lateral accretion) deposits, and

2) generally fine-grained cover (vertical accretion) deposits laid down over the riverbed deposits by streams at bank overflow (flood) stages.

Fpt – Old Floodplain Terrace: An old, elevated floodplain surface no longer subject to frequent flooding. Occurs as horizontal benches above present floodplains, and generally composed of materials very similar to active floodplains.

Gta – Ablation Till: Relatively younger ablation glacial till (Gta) deposits with more pronounced hummocky moraine topography and less dissected than the older basal till (Gtb). These late Wisconsin ablation till deposits are predominantly of Naptowne age (9,000 to 11,000 years ago), contain abundant cobbles and boulders, and consist of water-worked till (Woodward-Clyde Consultants, 1982).

GFo- Outwash: Course, granular, relatively level floodplains formed by a braided stream flowing from a glacier.

GFe – Esker Deposits: Long ridges of granular ice-contact deposits formed by streams as they flow in or under a glacier.

GFk – Kame Deposits: Hills, crescents and cones of granular ice-contact deposits formed by streams as they flow on or through a glacier.

L - Lacustrine Deposits: Generally fine-grained materials laid down in ancient Lake Ahtna and gravelly sands deposited in the Watana Creek – Stephen Lake pro-glacial lake.

Gtb – Basal Till: Basal glacial till sheets, with subdued moraine morphology, were likely deposited in the late Wisconsin, 11,000 to 25,000 years ago.

Bxu- Bedrock: In place rock that is overlain by a very thin mantle of unconsolidated material or exposed at the surface. The bedrock is not differentiated with respect to type or weathering/alteration.

## 4.1 Terrain Unit Properties and Engineering Interpretations

In order to evaluate the impact of a terrain unit with respect to specific project features, an interpretation of the engineering characteristics of each unit is provided below and summarized in the matrix on Table 1. The matrix shows the topographic position, areal extent, soil stratigraphy, and typical slopes of all units. Also included are physical property observations and engineering interpretations. The matrix is intended as a tool for general engineering planning and environmental assessment purposes so that site-specific development work can be minimized. The matrix is not suitable for design without the acquisition and analysis of additional laboratory and field information. A brief explanation of the observations, physical properties and engineering interpretations addressed in Table 1 are provided below (Acres, 1981).

### Soil Stratigraphy

An individual terrain unit, or landform, is made up of various soil types whose composition is a result of the mode of deposition. The mode of deposition affects the general character of the soil in terms of grain size, degree of sorting, particle shape, and layering.

### Slope Classification

Slopes in the project corridor have been divided into the following classes: Flat - 0 to 5 percent, Gentle - 5 to 15 percent, Moderate - 15 to 25 percent, and Steep - greater than 25 percent. References have been made to steep local slopes to account for small scarps and the similar short but steep slopes which characterize ice contact glacial drift.

### Probable Unified Soil Types

Based on the laboratory test results, field observations, previous work in similar areas, and definitions of the soils, a range of soil types has been assigned to each terrain unit, as defined by the Unified Soil Classification System (USCS) commonly used in engineering and geology to describe the texture and grain size of the soil. Often several soil types are listed, some of which are much less prevalent than others. Information in the soil stratigraphy column will aid in understanding the range and distribution of soil types. Borehole logs and lab test results can provide site specific USCS soil types.

### Drainage and Permeability in Unfrozen Soils

How the soils comprising the terrain units handle the input of water is characterized by their drainage and permeability. Permeability (hydraulic conductivity) refers to the rate at which water can flow through a soil. Drainage describes the wetness of the terrain unit, taking into account a combination of permeability, slope, topographic position, and the proximity of the water table.

## Ground Water Table

Anticipated depth to the ground water table is described in relative terms and is divided as follows: Very Shallow – 0 to 3 feet; Shallow – 3 to 20 feet; Moderately Deep – 20 to 50 feet; and Deep – greater than 50 feet. In construction involving excavation and foundation work, special techniques and planning will be required in most areas with a shallow water table and in some of the areas with a moderately deep water table. In areas of impermeable permafrost, a shallow perched local water table may occur.

## Suspected Permafrost Distribution

The occurrence of permafrost and the degree of continuity of frozen soil is described in Table 1 by the following terms (Jorgenson et al., 2008):

- Absent - 0%
- Isolated - >0 to 10%
- Sporadic - 10 to 50%
- Discontinuous – 50 to 90%
- Continuous - >90%

## Erosion Potential

Erosional potential, as described here, considers the likelihood of the material being moved by eolian and fluvial processes such as sheetwash, rill and gully formation, and larger channelized flow. In general this relates to particle size of the soil, however, the coarse sediments of floodplains have been rated as high because the surface is very active, and likewise coarse terrace deposits can have a high rating because of their proximity (by virtue of their origin) to streams. (Mass wasting potential is considered under slope stability).

## Frost Heave Potential

Those soils which contain significant amounts of silt and fine sand have the potential to produce frost heave problems. A three-level classification of frost heave potential is based on the percentage of soils (by weight) that pass the 0.02 mm sieve: 6-10% passing is Low, 10-20% passing is Moderate, and greater than 20% passing is High. Where the soil stratigraphy is such that a frost susceptible soil overlies a coarse-grained deposit, a dual classification is given; for these soils it may be possible to strip off the frost susceptible material.

### Thaw Settlement Potential

Permafrost soils with a significant volume of ice may show some settlement of the ground surface upon thawing (thaw strain). For the three-level classification of thaw settlement potential, a thaw strain less than 10% is Low, 10-25% is Moderate, and greater than 25% is High. In general, clays, silts and fine sands have the greatest settlement potential, forming the basis for the three-fold classification presented on the chart. Unfrozen soils and bedrock do not have the potential for thaw settlement. Thawing problems may be initiated or accelerated by disturbance of the surficial soil layers or the organic mat.

### Bearing Strength

Based on the terrain unit soil types and stratigraphy, a qualitative description of bearing strength is given. In general, coarse-grained soils have a higher bearing strength than fine-grained soils, but the presence of permafrost may significantly increase the strength of some fine-grained soils (as indicated on the matrix by the thermal state qualifying statement).

### Slope Stability

The slope stability qualitative rating was derived through evaluation of each terrain units' topographic position, slope, soil composition, water content, ice content, etc. The stability assessment considers rapid mass wasting processes (slump, rock slide, debris slide, mudflow, etc.) and slower progressive failures (creep, ravelling). Several terrain units which have characteristically gentle slopes and are commonly in stable topographic positions have been over-steepened by the recent, active undercutting of streams and/or man (or by older processes not currently active such as glacial erosion and tectonic uplift and faulting). The stability of the terrain units on over-steepened slopes and natural slopes is described on Table 1.

### Suitability as a Source of Borrow

Great quantities of borrow materials will be needed for all phases of construction. The rating considers suitability as pit run and processed aggregate or impervious core and takes into account the materials present as well as the problems associated with extracting material from the various terrain units.

## 5.0 REFERENCES

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**TABLES**

**Table 1: Terrain Unit Properties and Engineering Interpretations**

| LABELS | NAMES | MORPHOLOGY | PHYSICAL PROPERTY OBSERVATIONS | | PHYSICAL PROPERTY INTERPRETATIONS | | | ENGINEERING INTERPRETATIONS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Terrain Unit Symbol** | **Terrain Unit Name** | **Topography and Areal Distribution** | **Soil Stratigraphy** | **Slope Classification** | **Suspected Unified Soil Types** | **Drainage & Permeability in Unfrozen Soils** | **Ground Water Table** | **Suspected Permafrost Distribution** | **Erosion Potential** | **Frost Heave Potential** | **Thaw Settlement Potential** | **Bearing Strength** | **Slope Stability** | **Suitability as Source of Borrow** |
| **O** | Organic deposits | In swales between small rises on lowlands and in high elevation bedrock areas. Flat surface to steplike terraces. | Decomposed and undecomposed organic material with some silt. | Flat | PT, OL | Poor/Moderate to High | At Surface | Discontinuous | Low | High | High | Very Low | Low | Nil |
| **C** | Colluvial deposits | Predominantly found at the base of steeper bedrock slopes as coalescing cones and fans and rock glacier. | Angular frost cracked, blocks of rock, some silt and sand. | Moderate to Steep | GP, GW, GM SW, SM | Good/High | Deep | Sporadic at Low Elev, Discontinuous at High Elev. | Moderate to High | Low to High | Low to Moderate | Low to Moderate | Low to Moderate | Fine - Poor Coarse - Variable |
| **Cl** | Active landslide | Hummocky unconsolidated deposits most common along the Susitna River and its major tributaries. Typically not forested. | Silty gravels, silty sands and sandy silts; possible crude contorted layers. | Moderate to Steep | GM, SM, ML | Poor/Low | Shallow (perched) | Sporadic | High | High | High where frozen | Low | Low | Poor |
| **Cl-i** | Inactive landslide | Hummocky unconsolidated deposits most common along the Susitna River and its major tributaries. Typically forested. | Silty gravels, silty sands, and sandy silts: possible crude contorted layers | Moderate to Steep | GM, SM, ML | Poor/Low | Shallow (perched) | Sporadic | High | High | High where frozen | Low | Low | Poor |
| **Cs** | Solifluction deposits | Relatively smooth to lobate topography created by the flow of material subjected to frequent freeze/thaw cycles. | Silty sand and sandy silt showing contorted layering. | Gentle to Steeply Sloping | SW, SM, ML | Frozen | Shallow (perched) | Discontinuous to Continuous | High | High | High | High | Low | Poor |
| **Ffg** | Granular alluvial fan | Low, cone shaped deposits formed where high gradient streams flow onto flat surfaces. | Rounded cobbles and gravel with sand and some silt, some sorting and layering of materials. | Moderate | GW, SW | Good/High | Shallow | Isolated | Moderate | Low | Low | High | High | Fine - Poor Coarse - Good |
| **Fp** | Floodplain | Flat plains, slightly above and adjacent to the present Susitna River and its major tributaries. | Rounded cobbles, gravel and sand sorted and layered. With or without silt cover. | Flat to Gentle | GW, GP, SW SP, SM | Good/High | Very Shallow | Isolated | High | Generally Low (High for surface cover) | Low | Surficial Silts Low, Sands & Gravels High | High | Fine - Poor Coarse - Good |
| **Fpt** | Old floodplain terrace | Flat surface remnants of former floodplain deposits isolated above present floodplain. | Rounded cobbles, gravel and sand with some silt covered by a thin silt layer. Sorted and layered. | Flat to Gentle | GW, GP, SW, SP, SM, ML | Good/High | Deep | Isolated | Low | Generally Low (High for surface cover) | Low | High | Low to Moderate | Fine - Poor Coarse - Good |
| **GFo** | Outwash | Bottoms of U-shaped tributary valleys to the Susitna River. | Rounded and striated cobbles, gravel and sand. Crudely sorted and layered. | Gentle | GW, SW | Good/High | Shallow to Deep | Isolated | Moderate | Low | Low | High | Low to High | Fine - Poor Coarse - Excellent |
| **GFe** | Esker deposits | Rounded to sharp crested sinuous ridges in upper Susitna area. | Rounded and striated cobbles, gravel and sand. Crudely to well sorted and layered. | Steep Local Slopes | GW, SW | Good/High | Deep | Isolated | Moderate | Low | Low | High | Moderate | Fine - Poor Coarse - Excellent |

**Table 1: Terrain Unit Properties and Engineering Interpretations**

| LABELS | NAMES | MORPHOLOGY | PHYSICAL PROPERTY OBSERVATIONS | | PHYSICAL PROPERTY INTERPRETATIONS | | | ENGINEERING INTERPRETATIONS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **GFk** | Kame deposits | Rounded to sharp-crested, hummocky hills. | Rounded and striated cobbles, gravel and sand. Crudely sorted and layered. | Steep Local Slopes | GW, SW | Good/High | Deep | Isolated | Moderate | Low | Low | High | Moderate | Fine - Poor Coarse - Excellent |
| **Gta** | Ablation till | Tributary valley side walls and valley bottoms in general, between Tsusena and Deadman Creek hummocky rolling surface, numerous channels | Rounded and striated cobbles, gravel and sand. No sorting or layering. Boulder-cobble lag covering surface. | Gentle to Steep | GW, GM, SW SM | Moderate/ Moderate | Shallow to Moderately Deep | Unfrozen to Sporadic | Moderate | Low to Moderate | Low to Moderate | Moderate to High | Moderate | Fine - Poor Coarse - Fair |
| **L** | Lacustrine deposits | Flat to gently rolling terrain typically below an elevation of 3,000 feet. | Sandy silt and silty sand with occasional pebbles, to gravelly sand. Often sorted and layered. | Gentle | SP, SW, ML | Poor/Poor | Shallow (perched) | Discontinuous | High | High | High | Low if Thawed, High when Frozen | Low | Poor |
| **Gtb** | Basal till | Bottoms of larger U-shaped valleys and adjacent gentle slopes. | Gravely silty sand and gravely sandy silt; no layering or sorting; cobbles and boulders poorly rounded and striated. | Gentle to Steep | GM, SM, ML | Frozen | Shallow (perched) to Deep | Discontinuous | Moderate | High | High | Low if Thawed, High when Frozen | Low | Fine - Fair Coarse - Poor |
| **Bxu** | Undifferentiated bedrock | Cliffs in river canyon, rounded knobs on broad valley floor, and mountain peaks. | – | Gentle to Near Vertical | – | – | Deep | Discontinuous | Low | Nil | Nil | Very high | Moderate to high | Fine - Poor Coarse - Good |

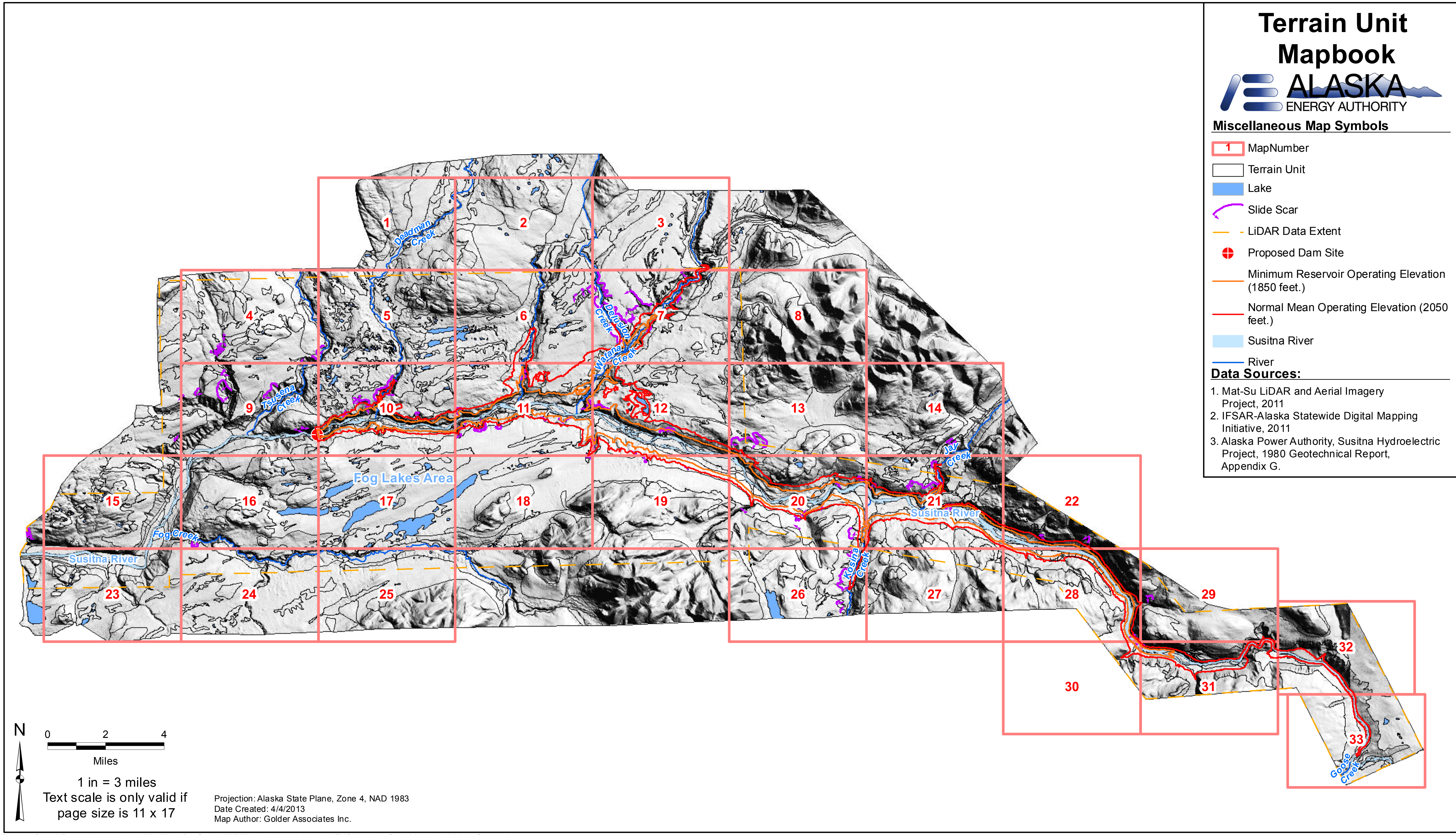
Table Reference: Modified from Acres, 1981, Susitna Hydroelectric Project, 1980-81 Geotechnical Report, prepared for Alaska Power Authority, V. 2, Appendix J.

EXPLANATION:

1. The individual terrain units or landforms listed above have been mapped independently and as compound (i.e. L/Gtb) or complex (i.e. C/Bxu + Bxu) terrain units.
2. Compound terrain units result when one landform overlies a second recognized unit at a shallow depth (less than 25 feet), such as a thin organic deposit overlying lacustrine sediments (i.e. O/L).
3. Complex terrain units have been mapped where the surficial exposure pattern of the landforms are so intricately related that they must be mapped as a combination of single symbols (i.e. C/Bxu + Bxu).

**FIGURES**

**TERRAIN UNIT MAPBOOK [INDEX SHEET AND MAPS 1 THROUGH 33]**

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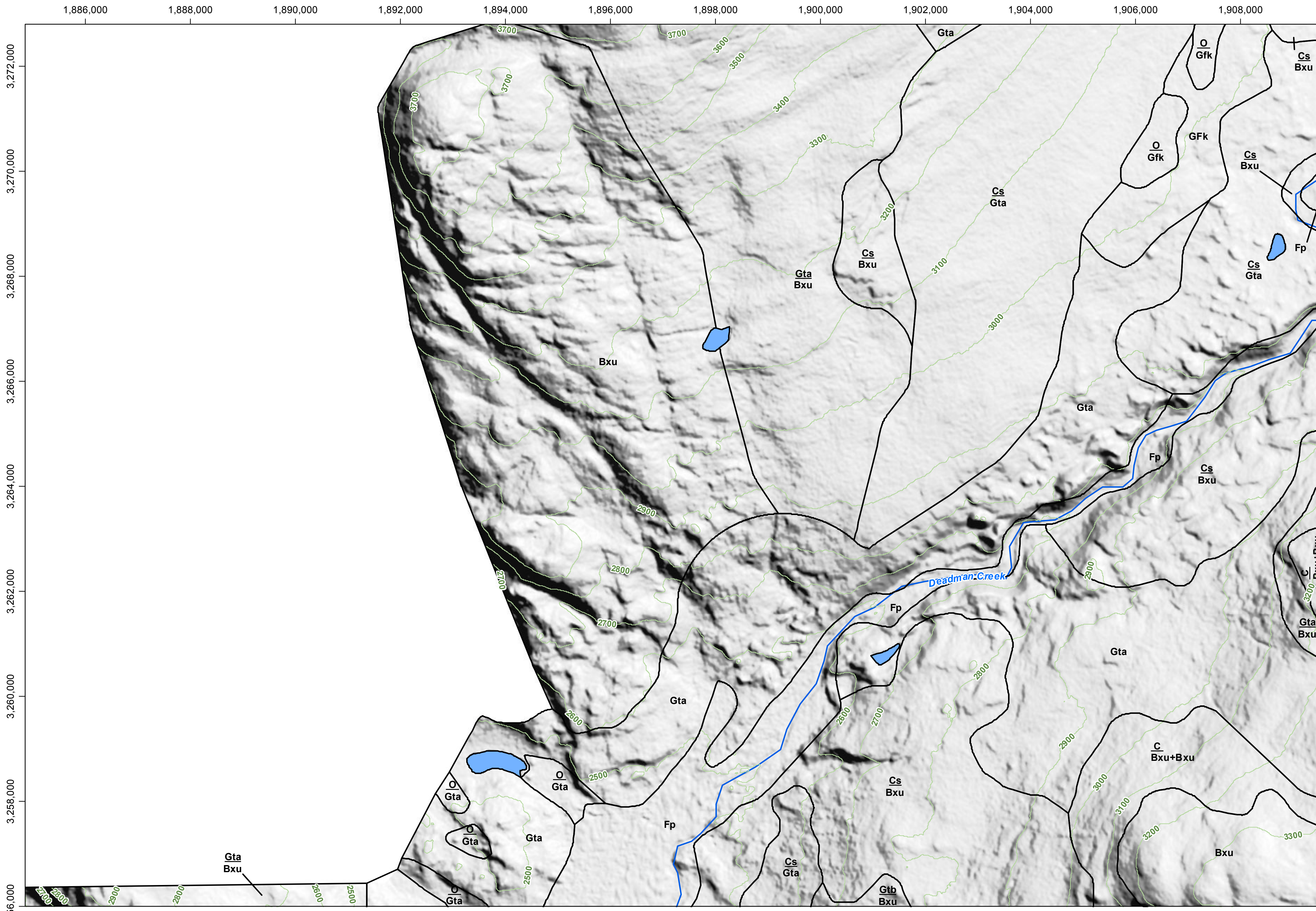


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| Cs | Solifluction deposits |
| Ffg | Granular alluvial fan |
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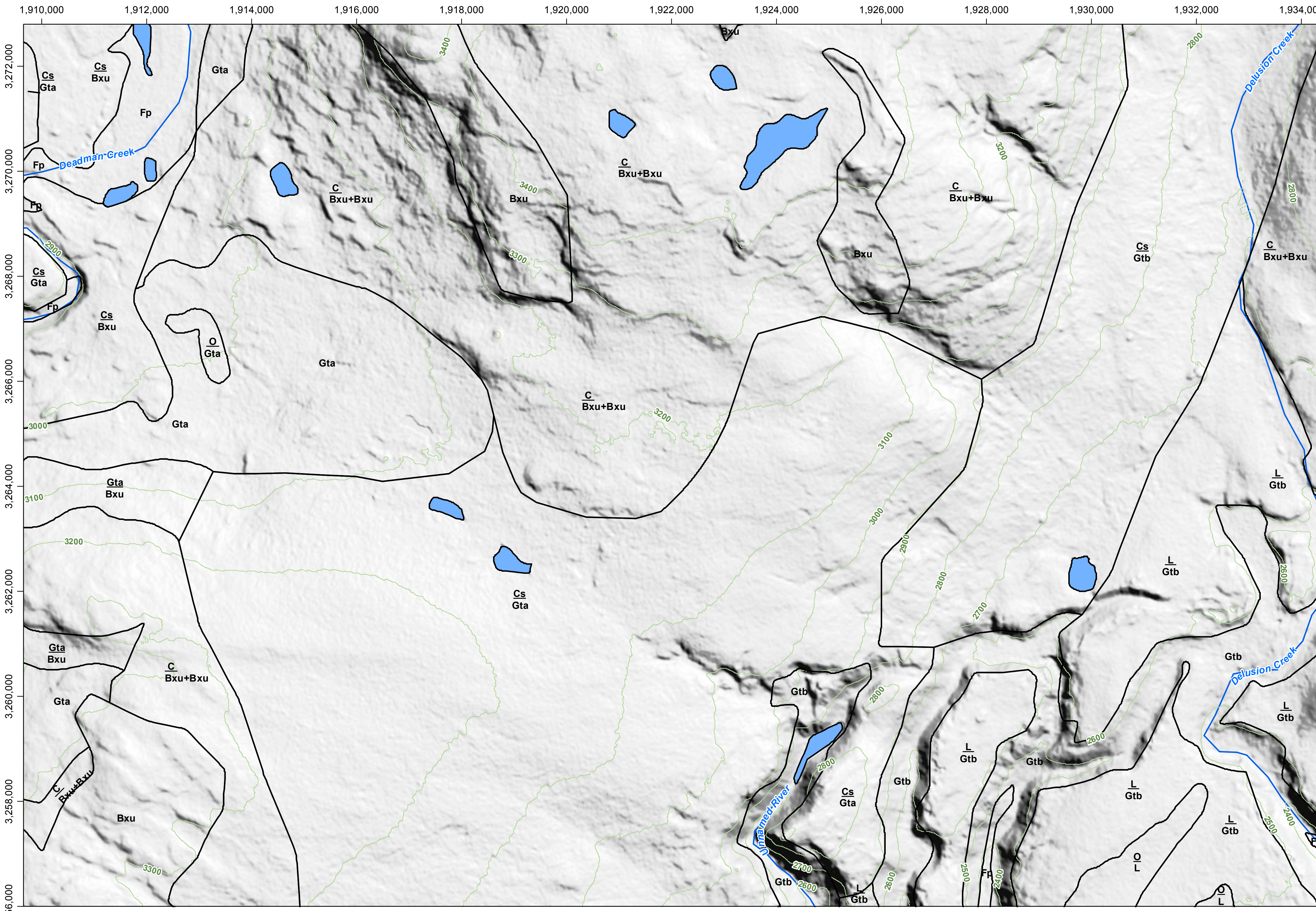


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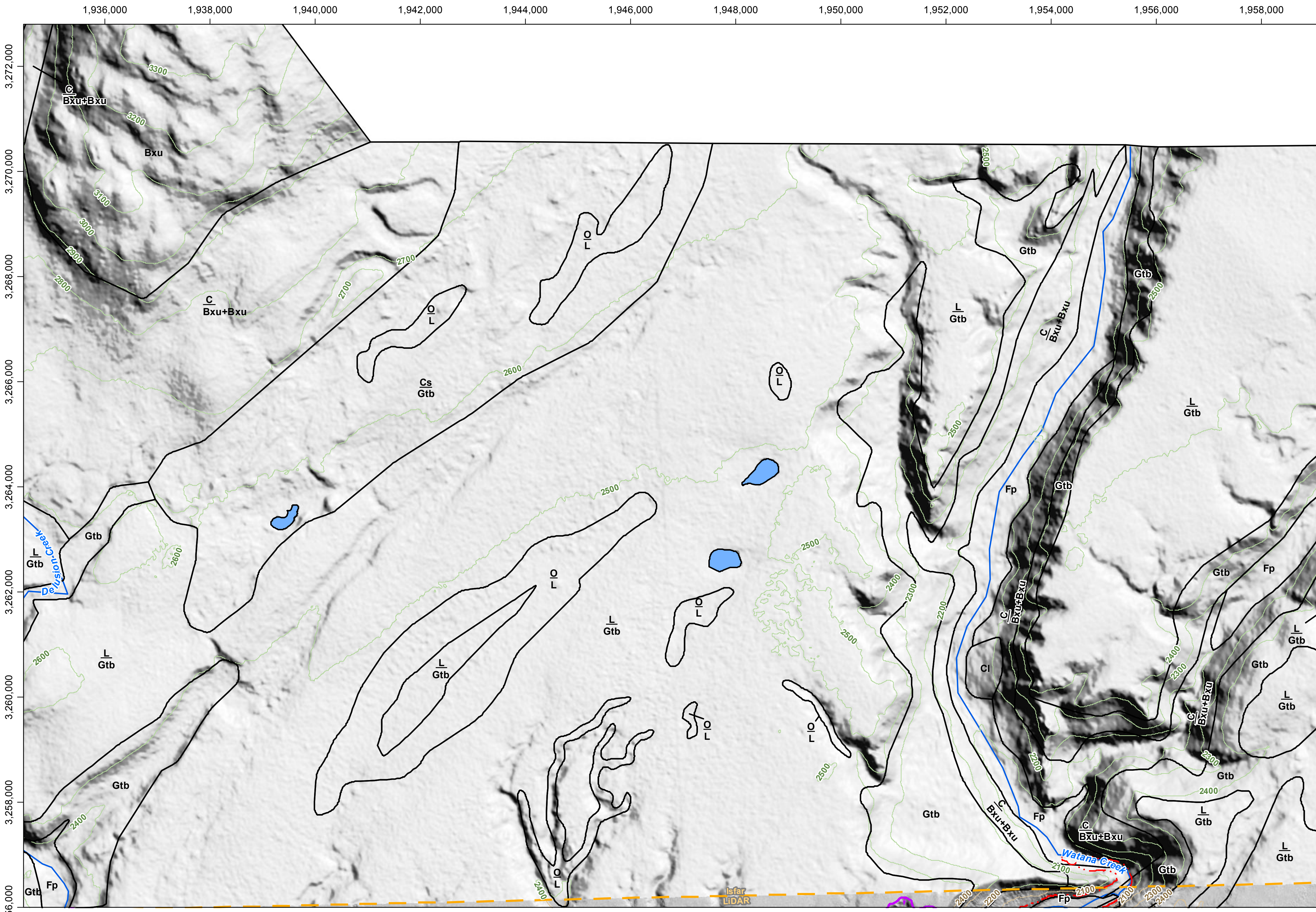


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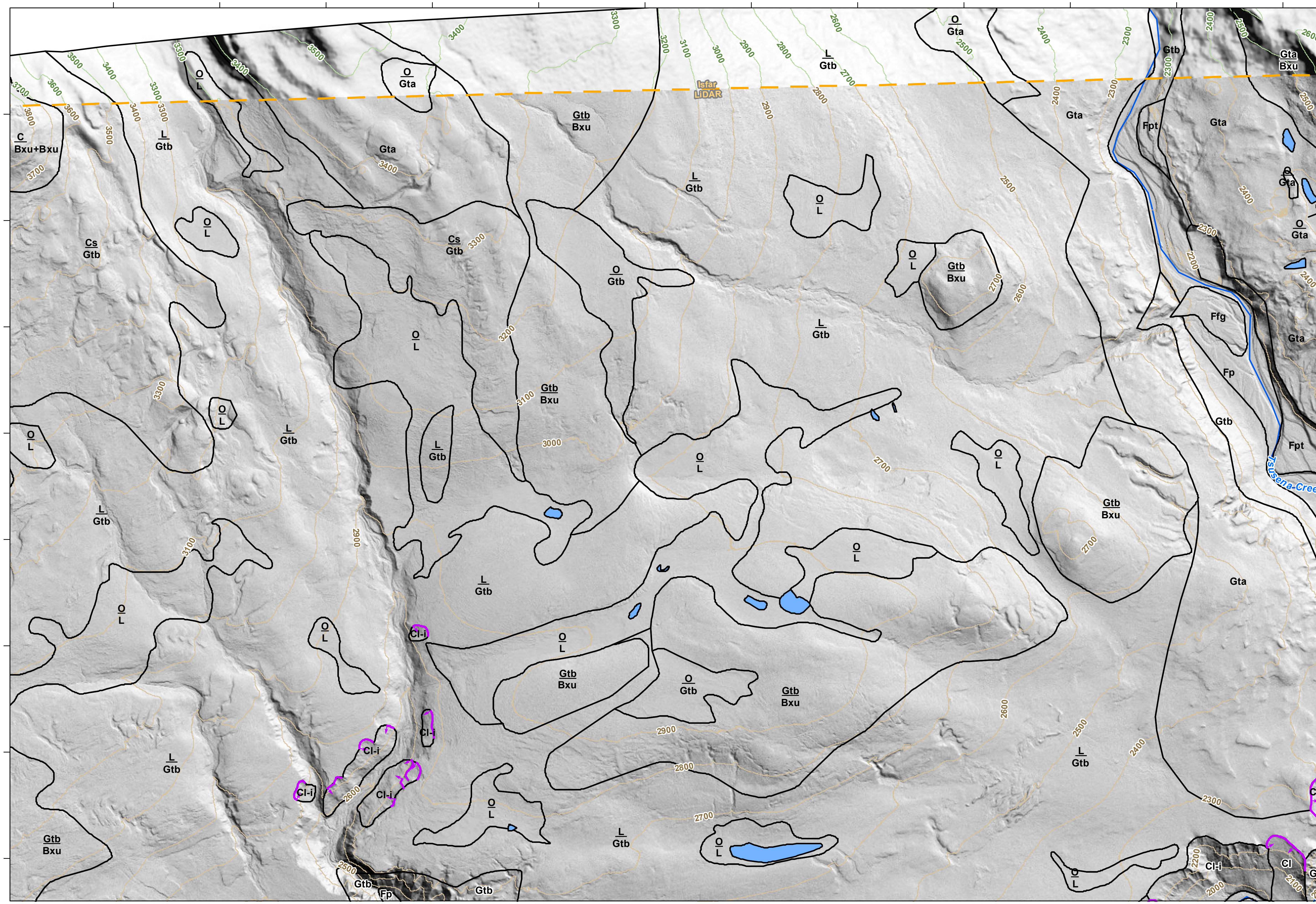


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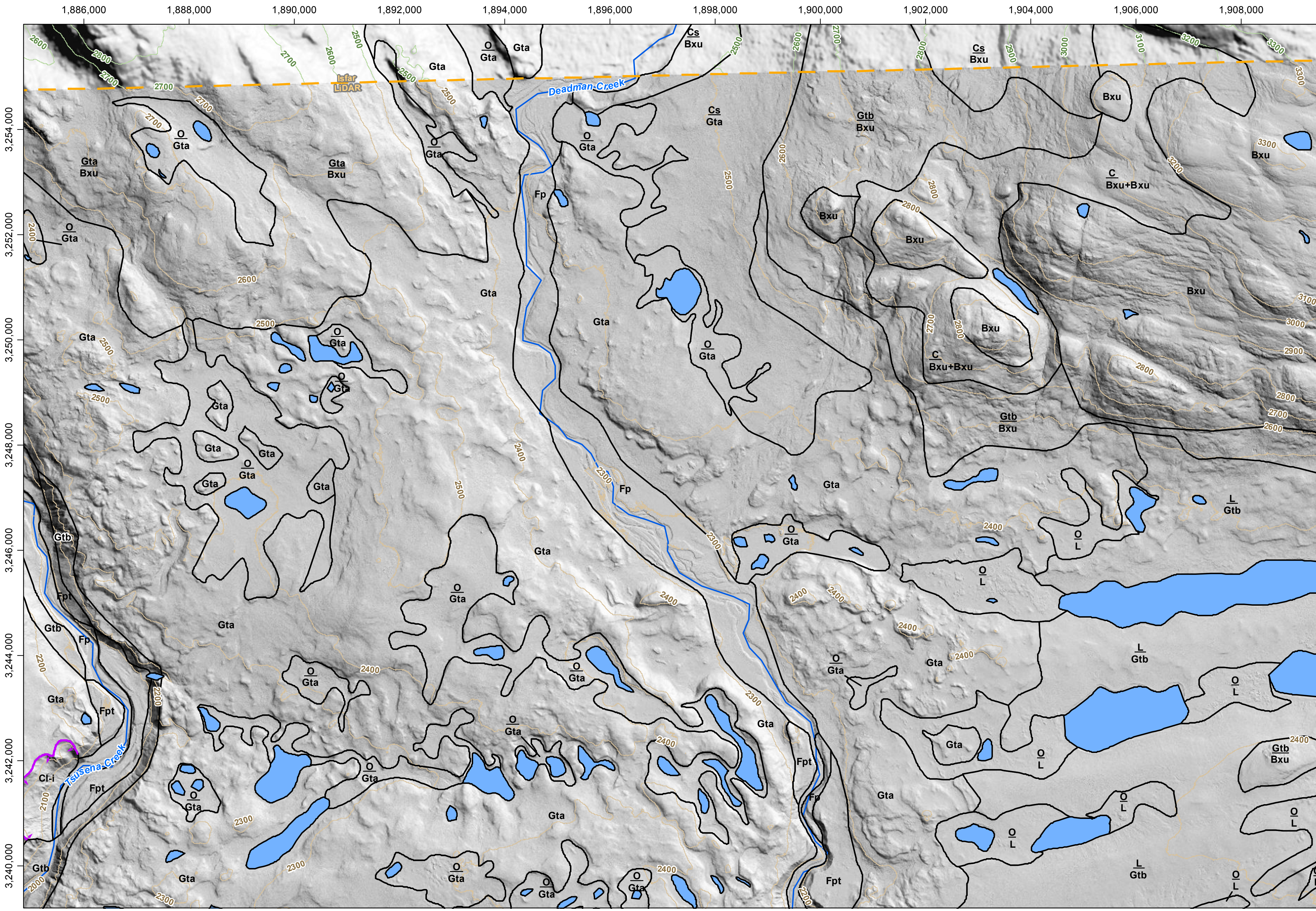


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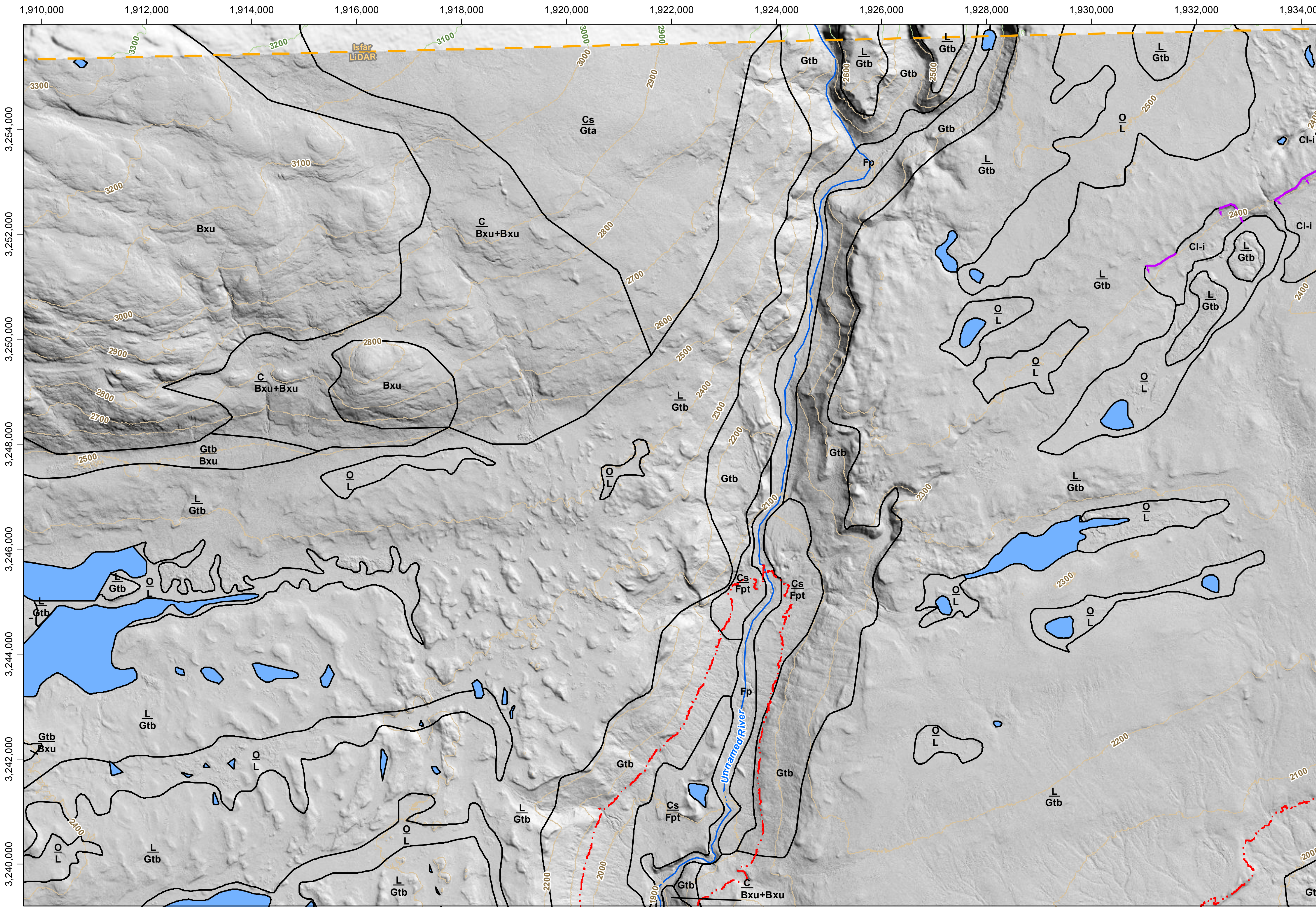


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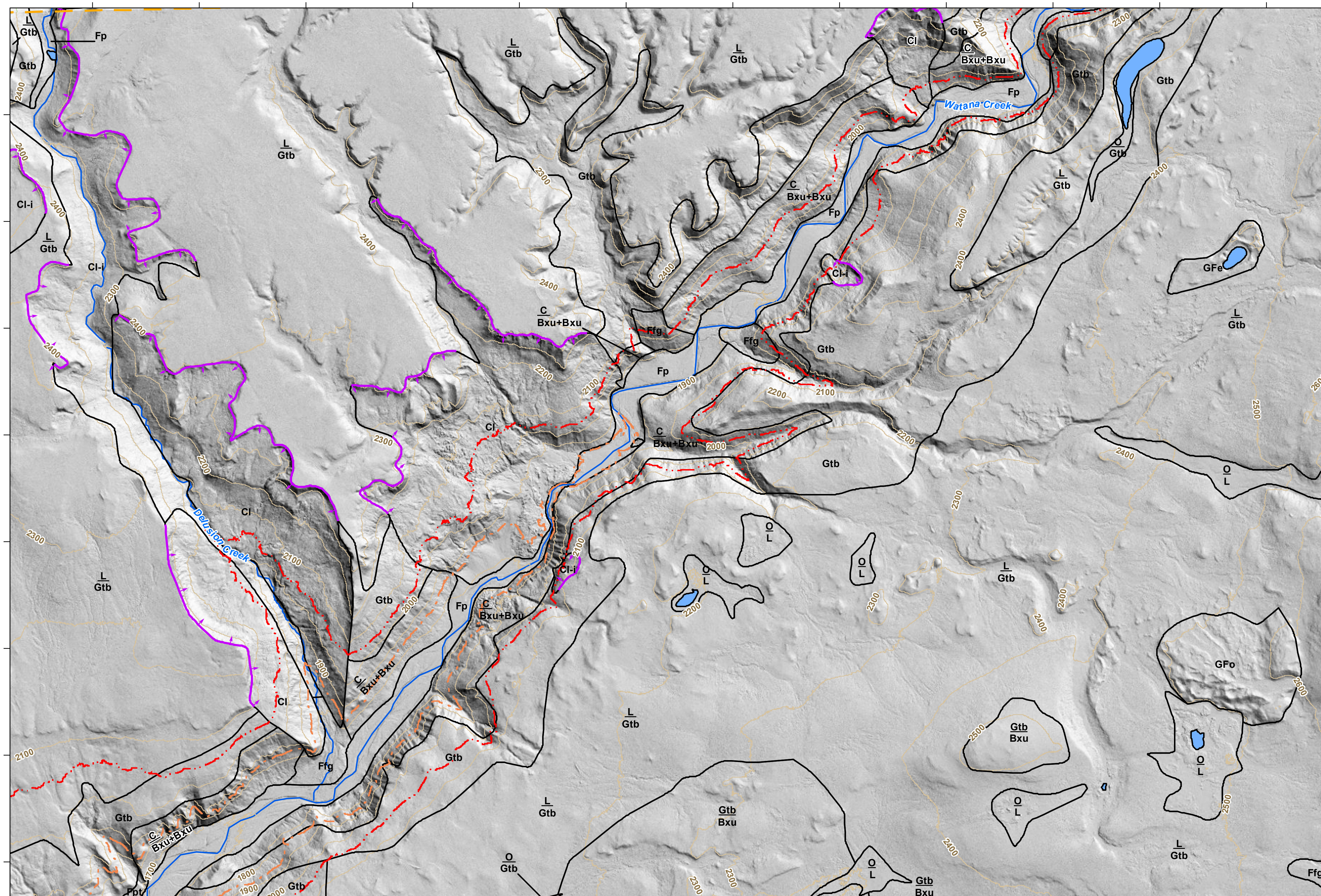


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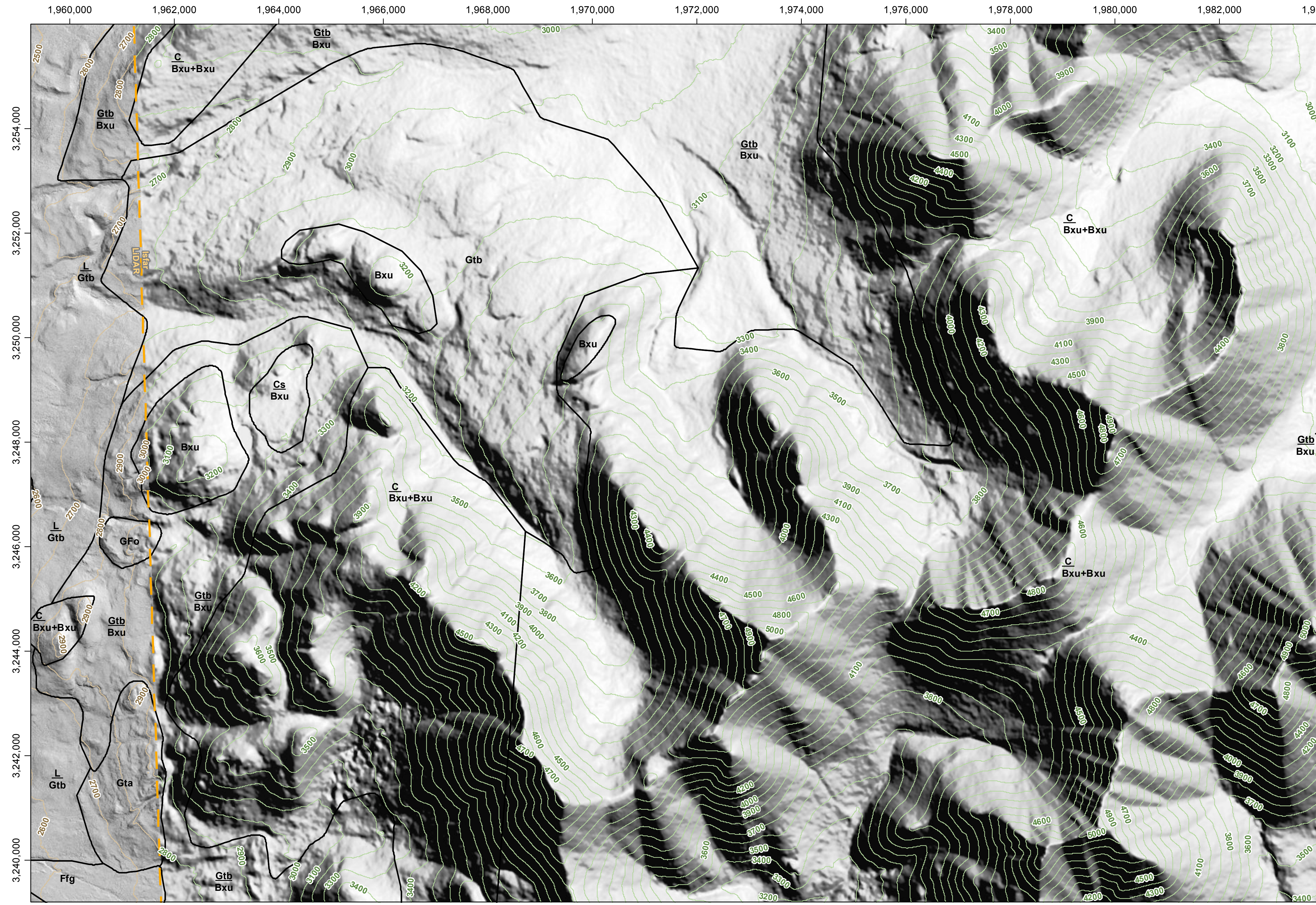


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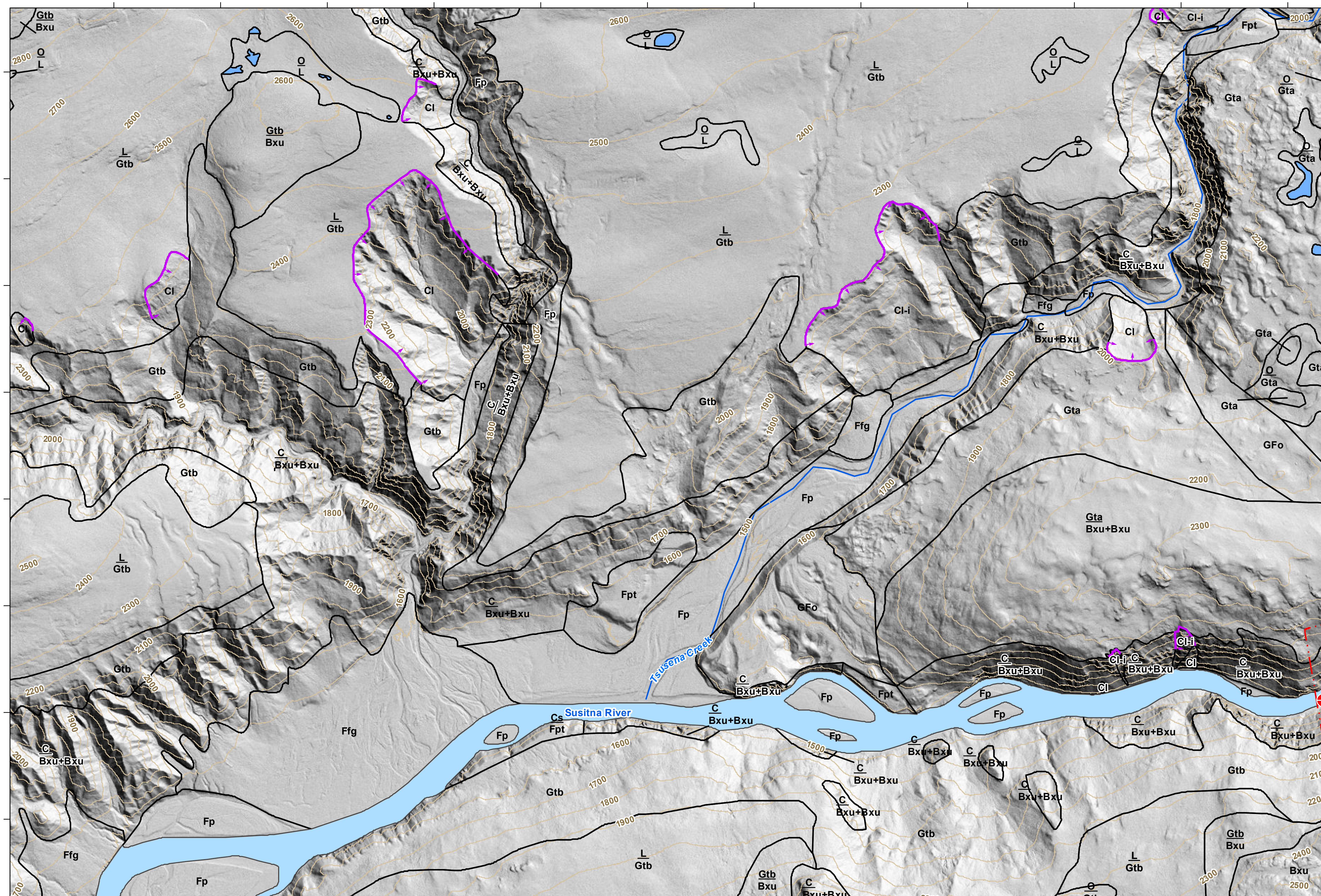


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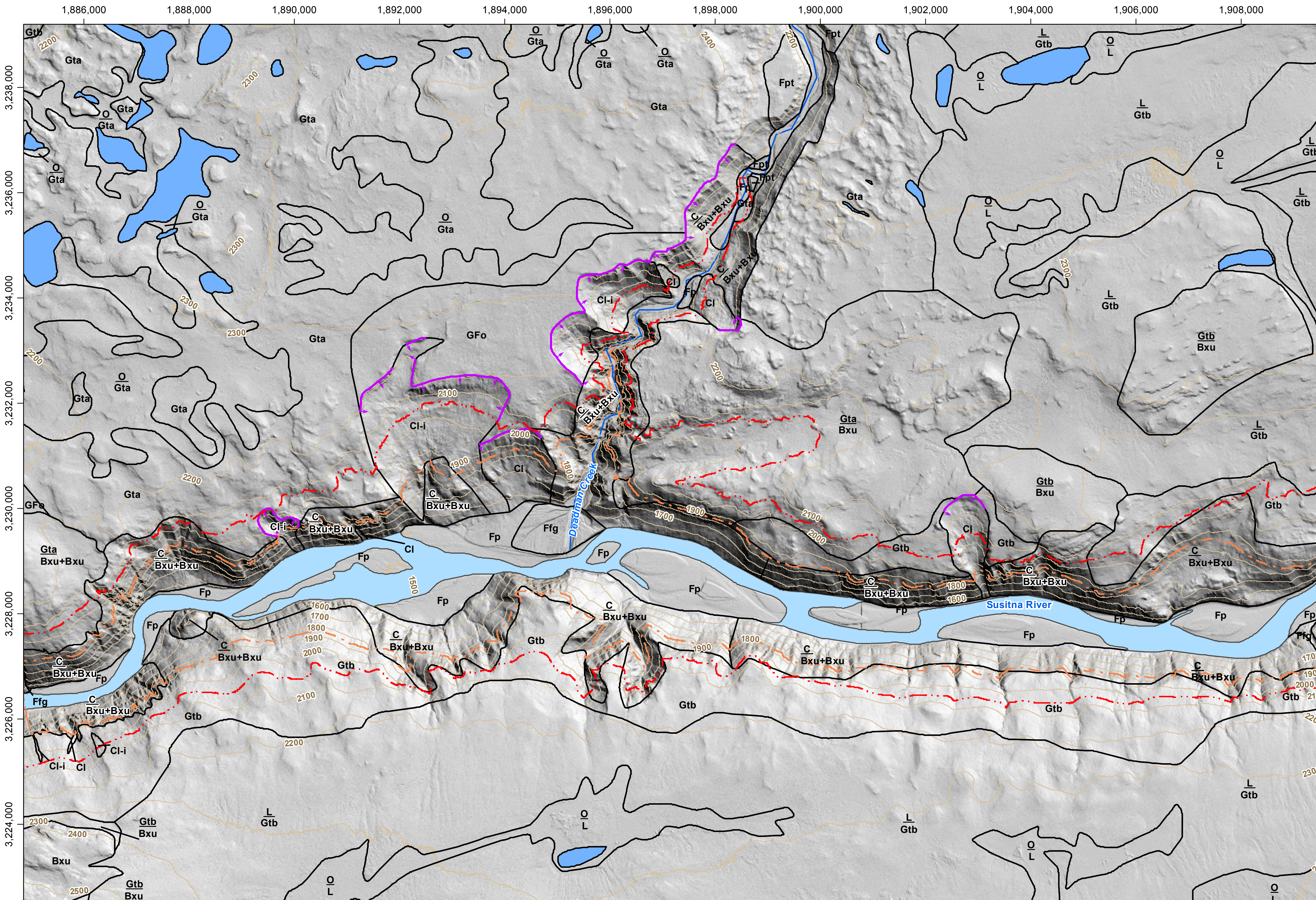


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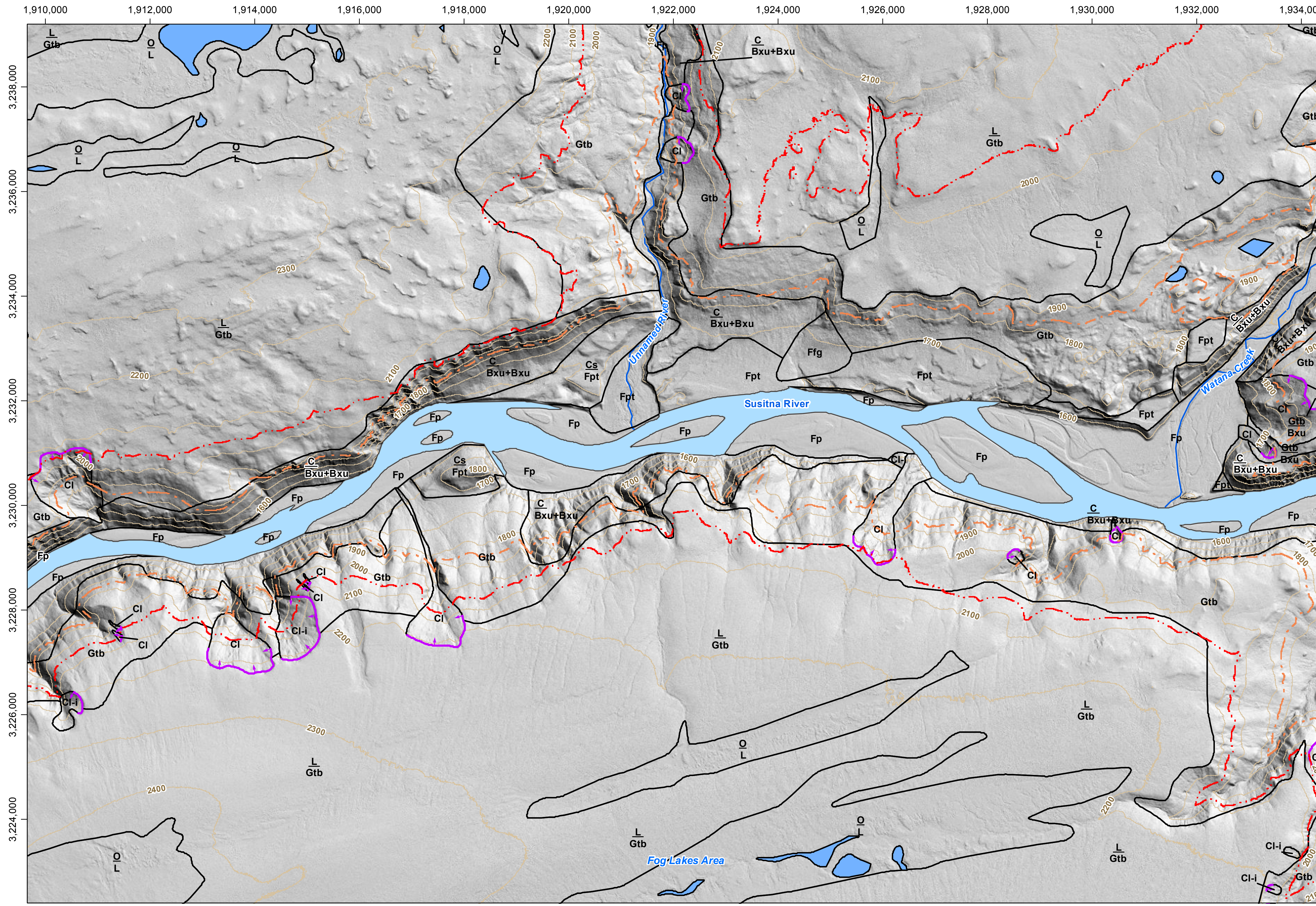


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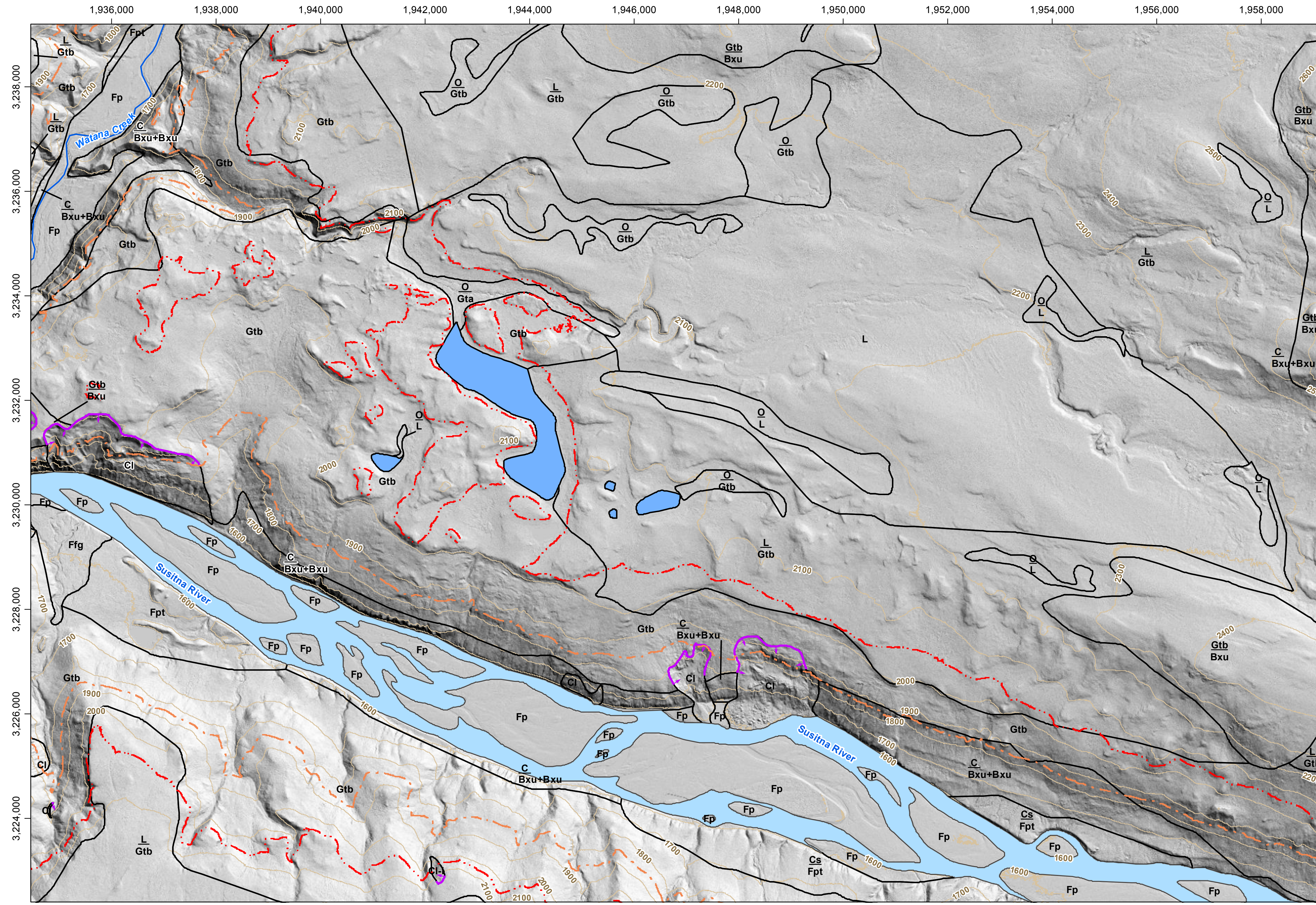


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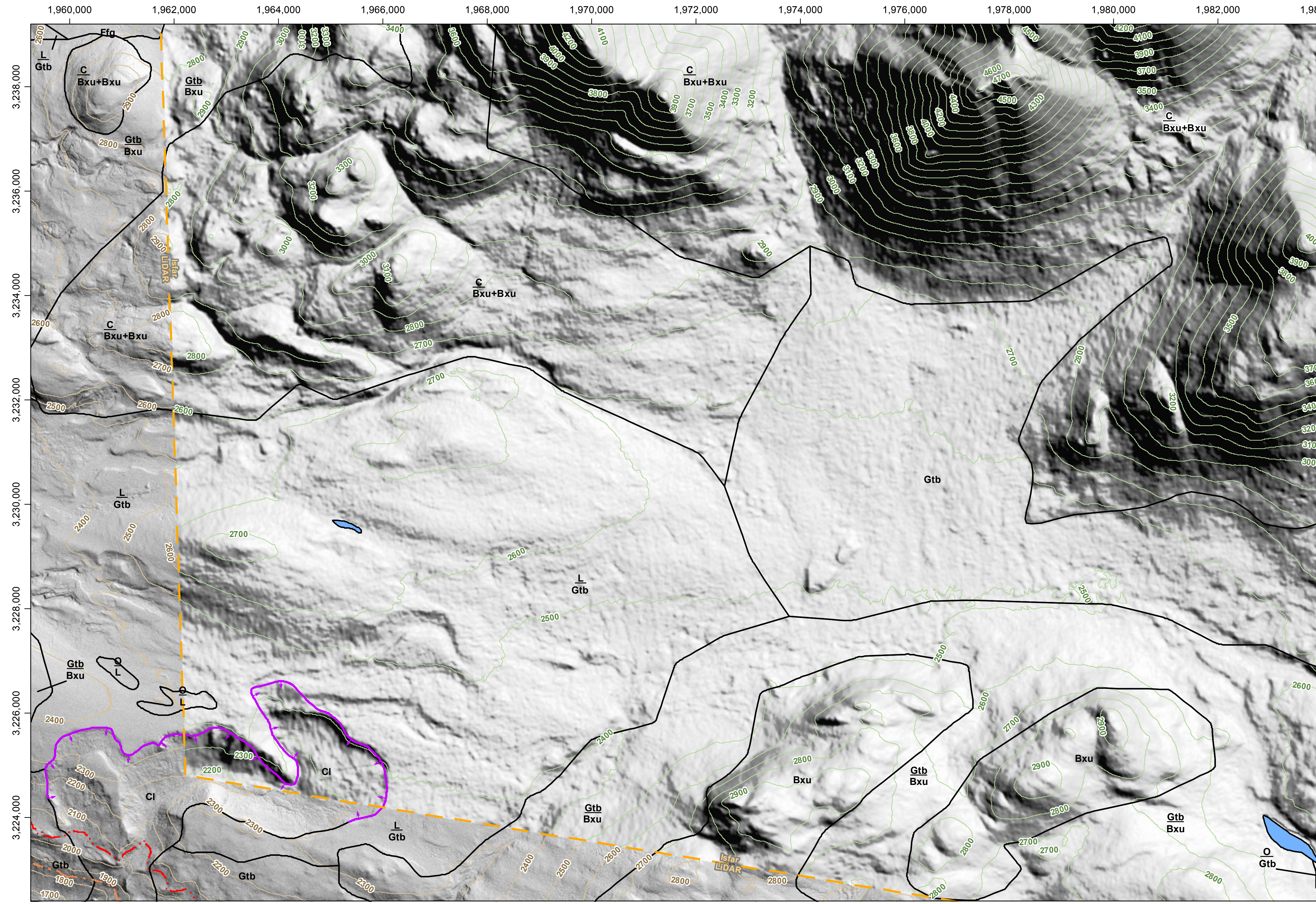


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| GFe | Esker deposits |
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| L | Lacustrine deposits |
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ALASKA ENERGY AUTHORITY

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Feet

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N

Projection: Alaska State Plane, Zone 4, NAD 1983
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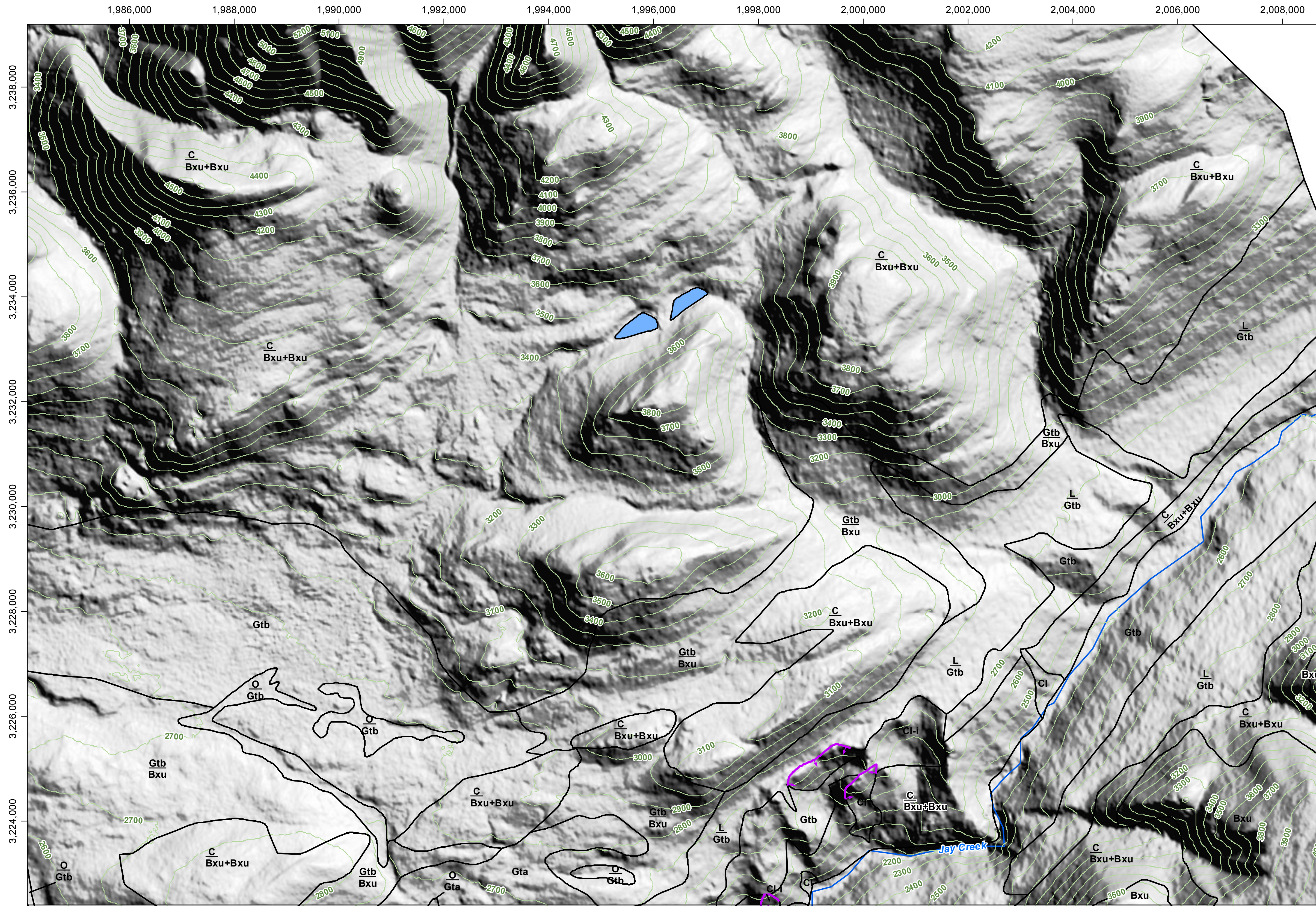
Map Author: Golder Associates Inc.

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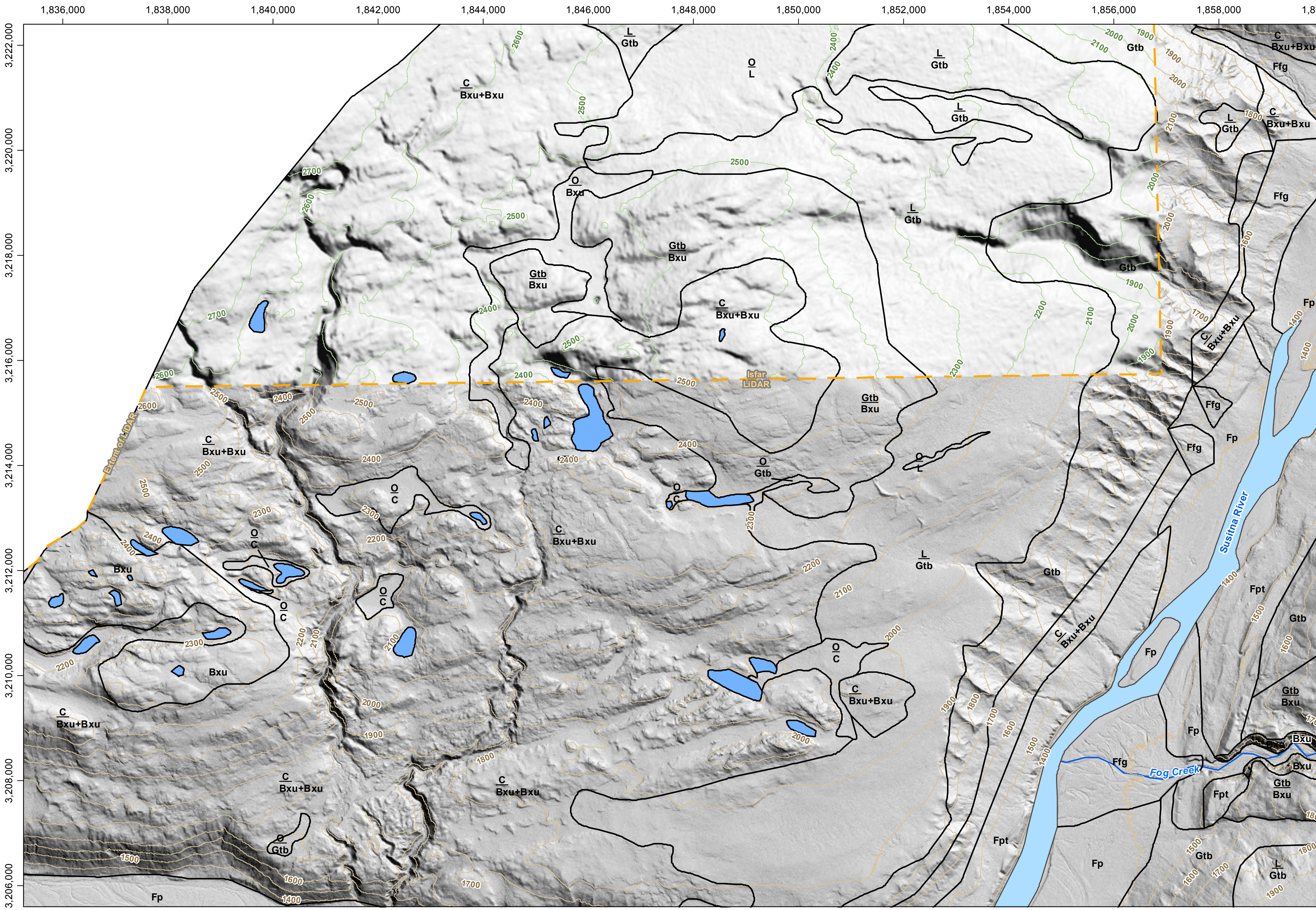


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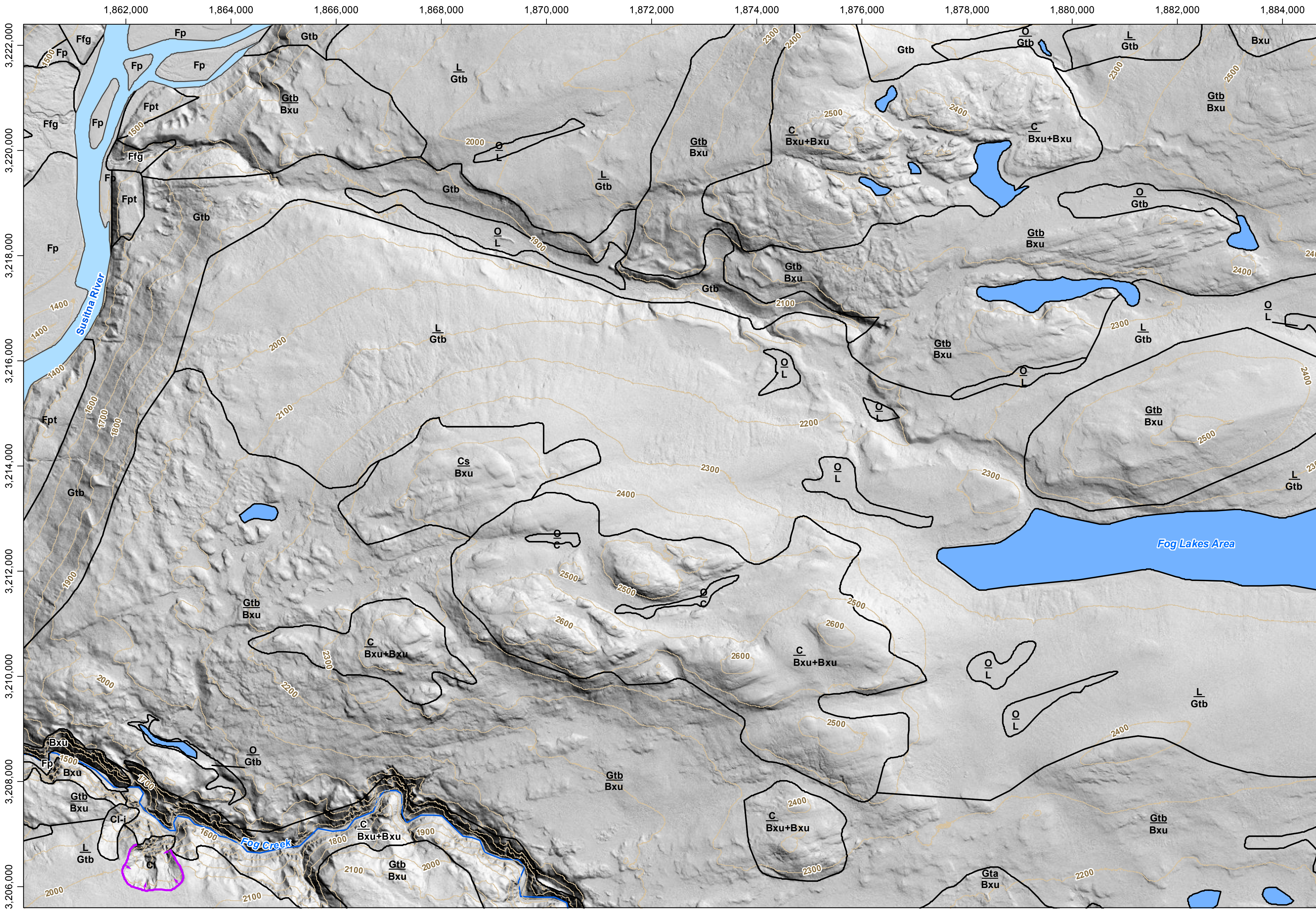


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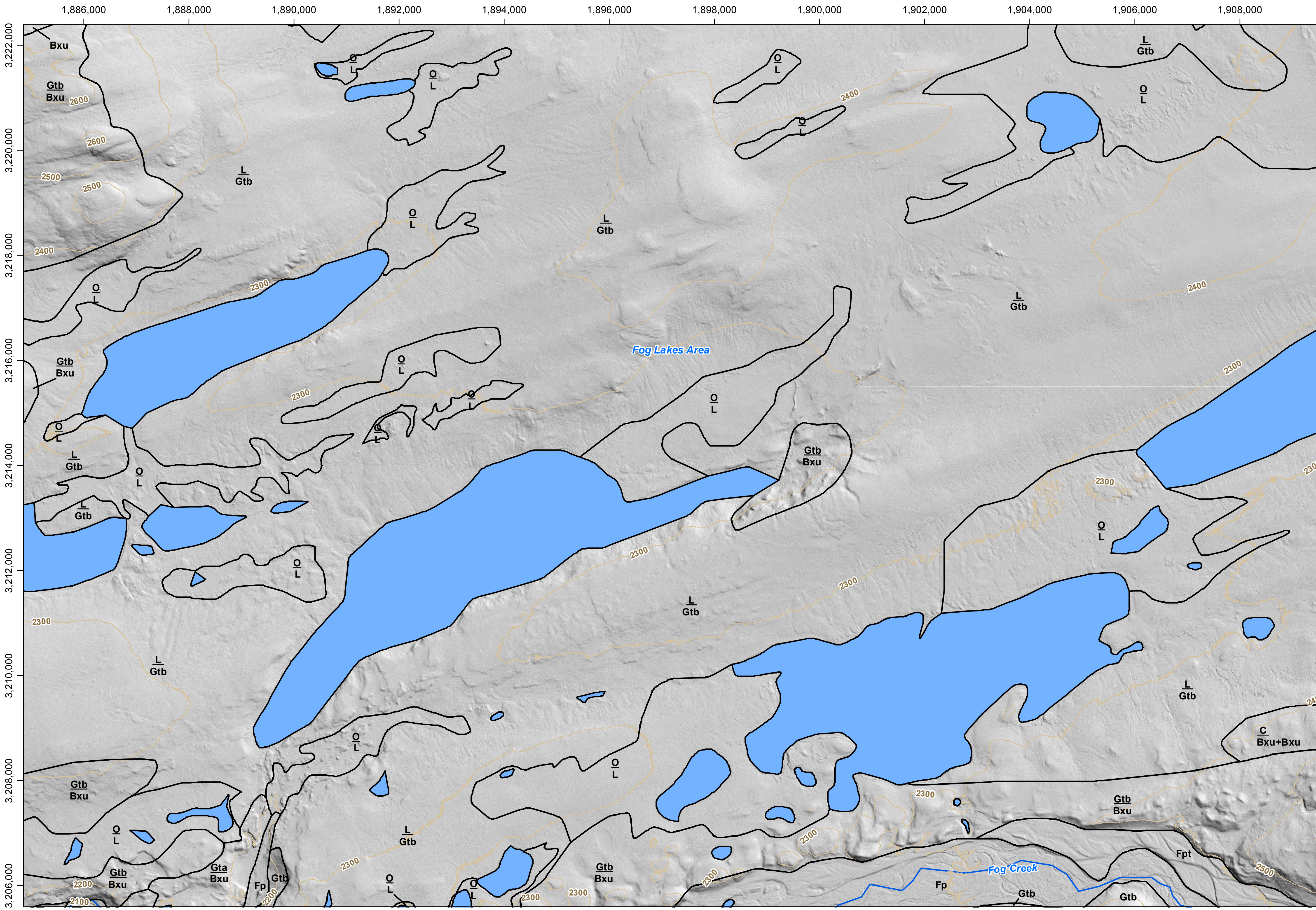


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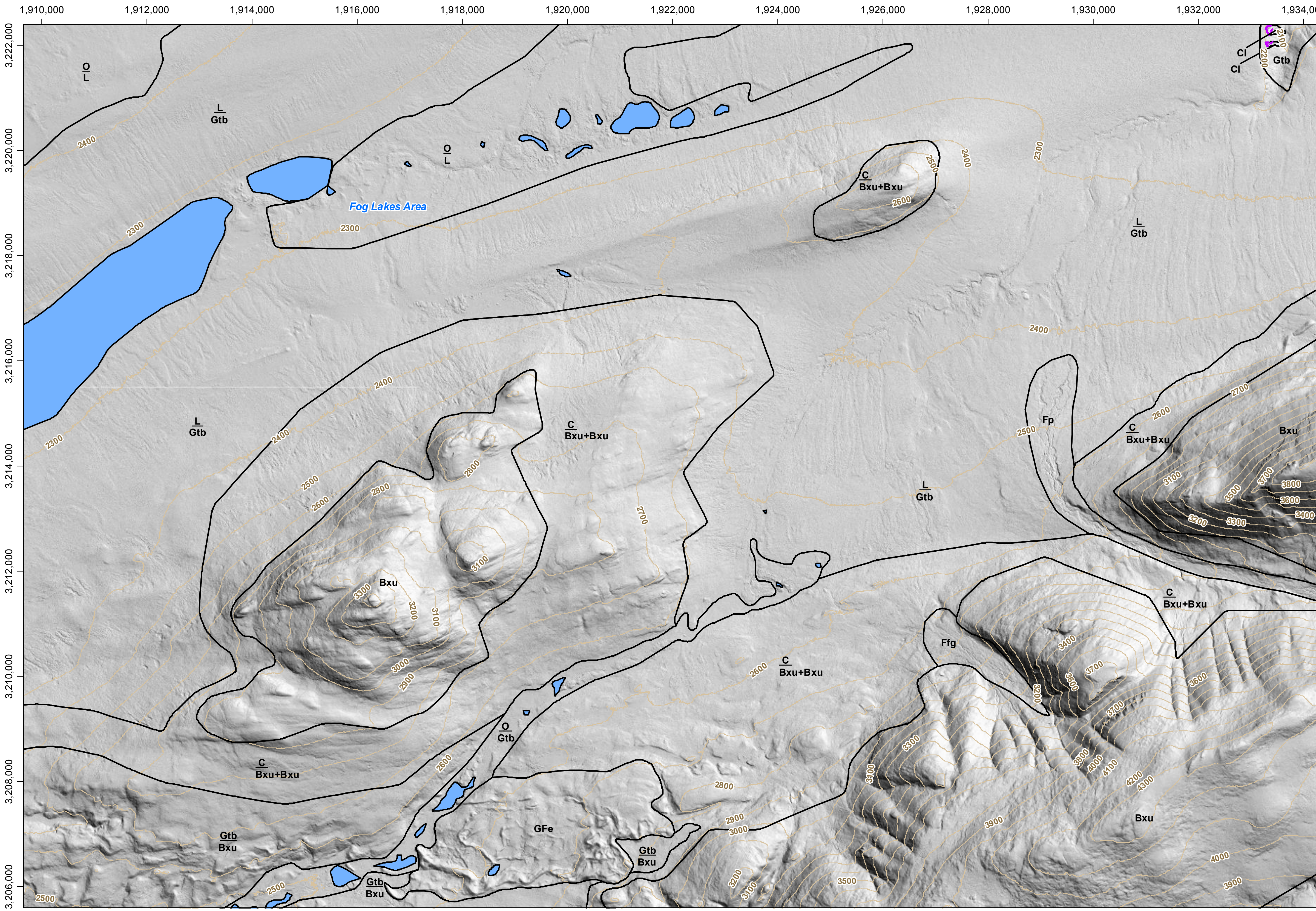


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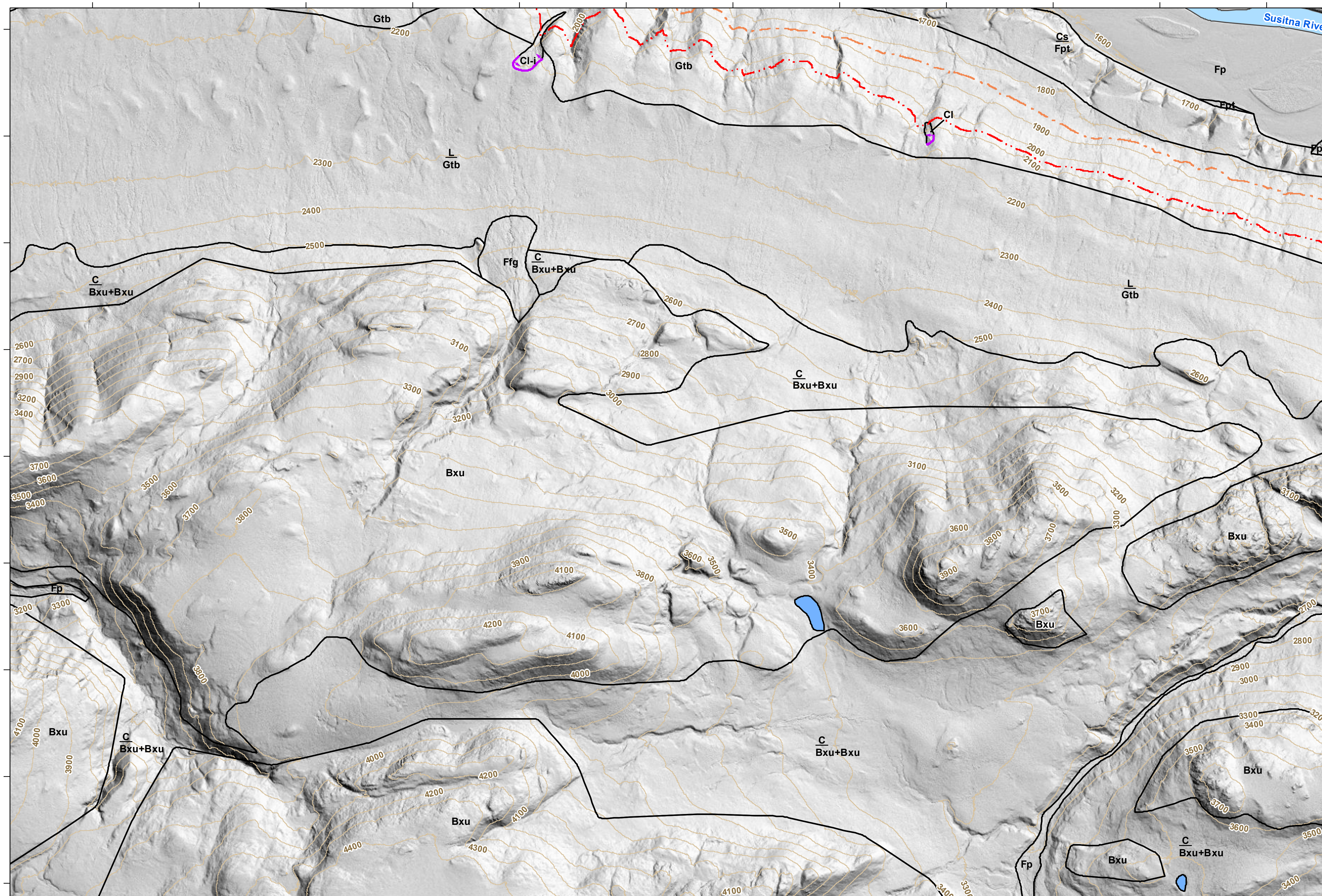


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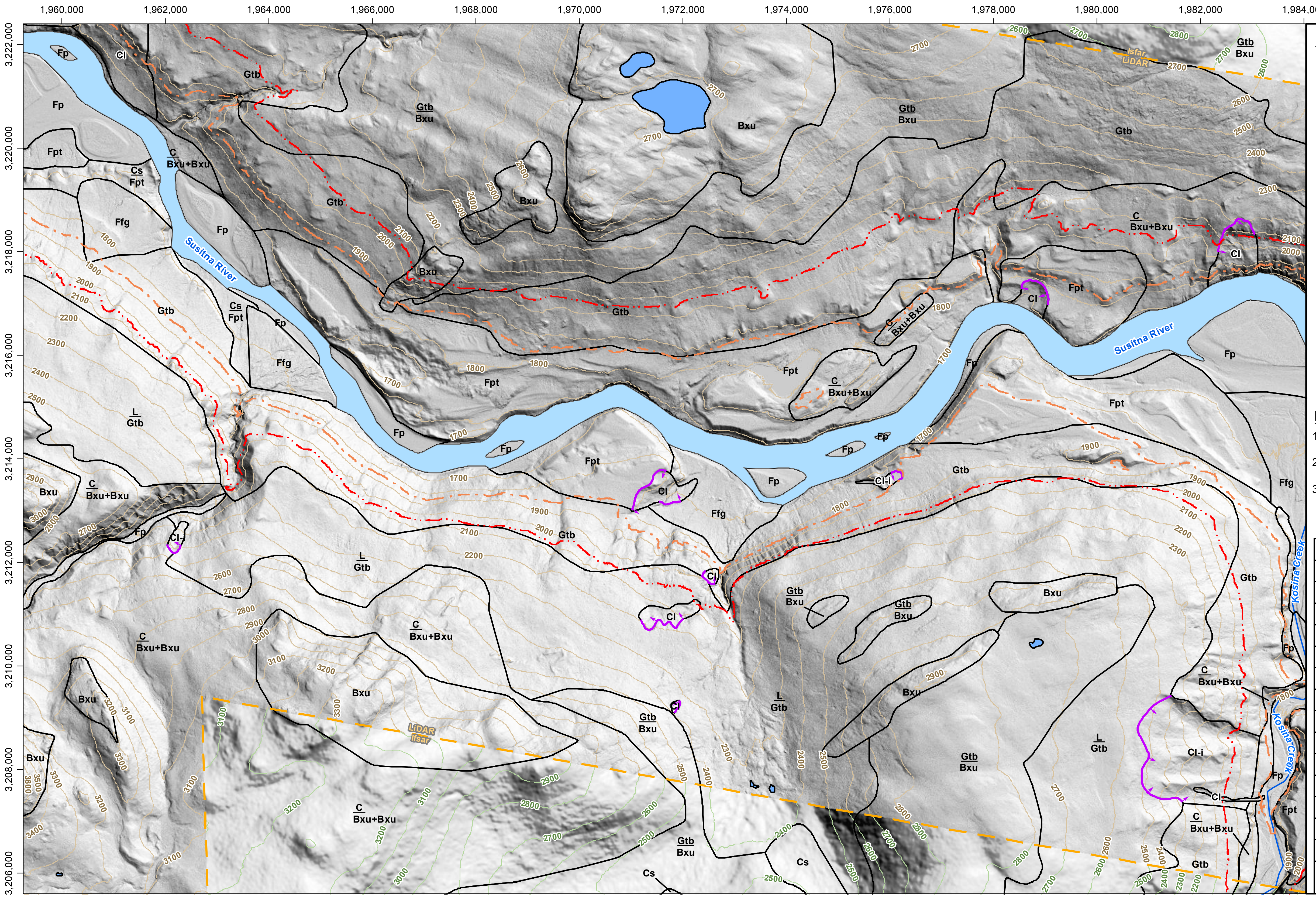


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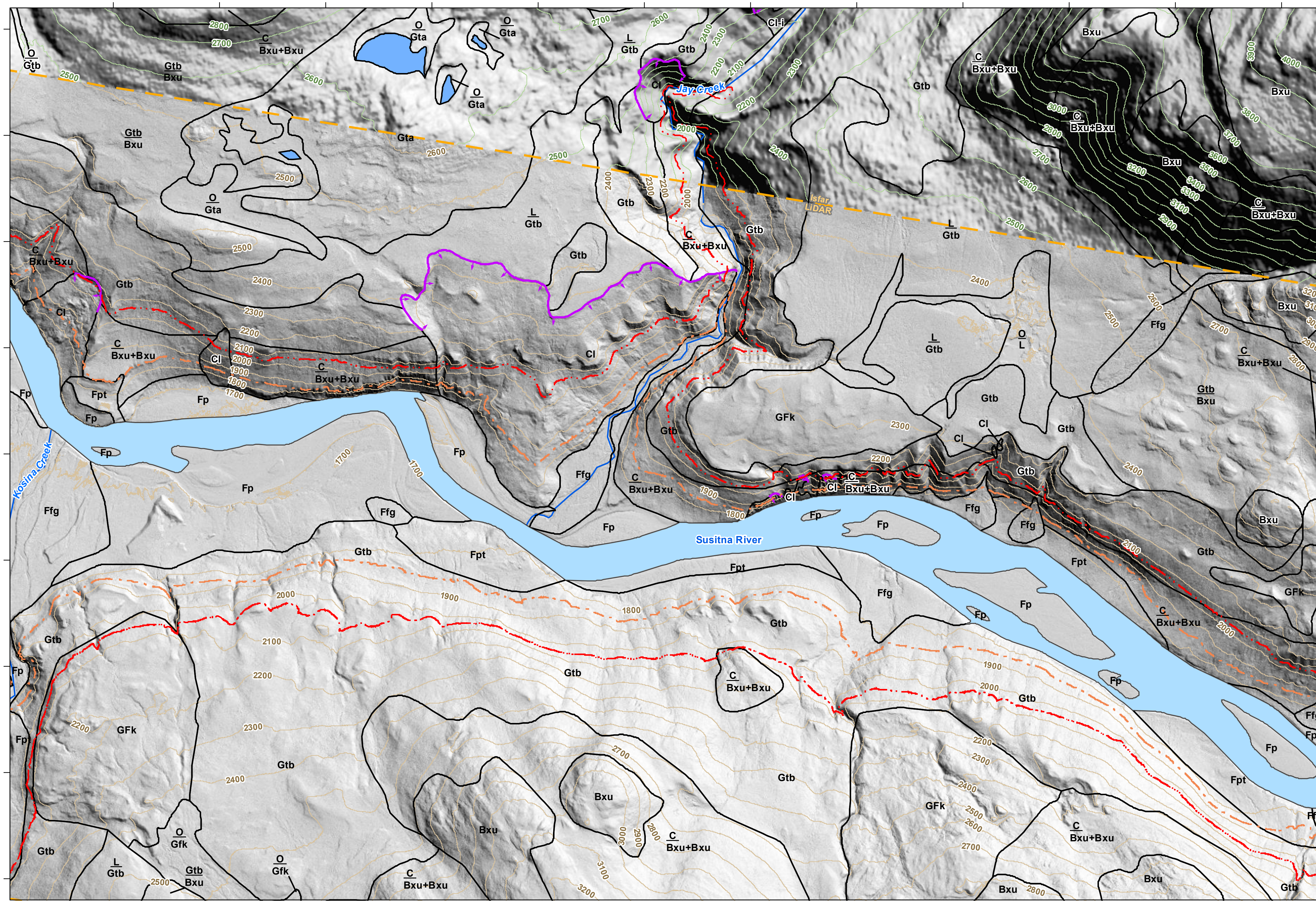


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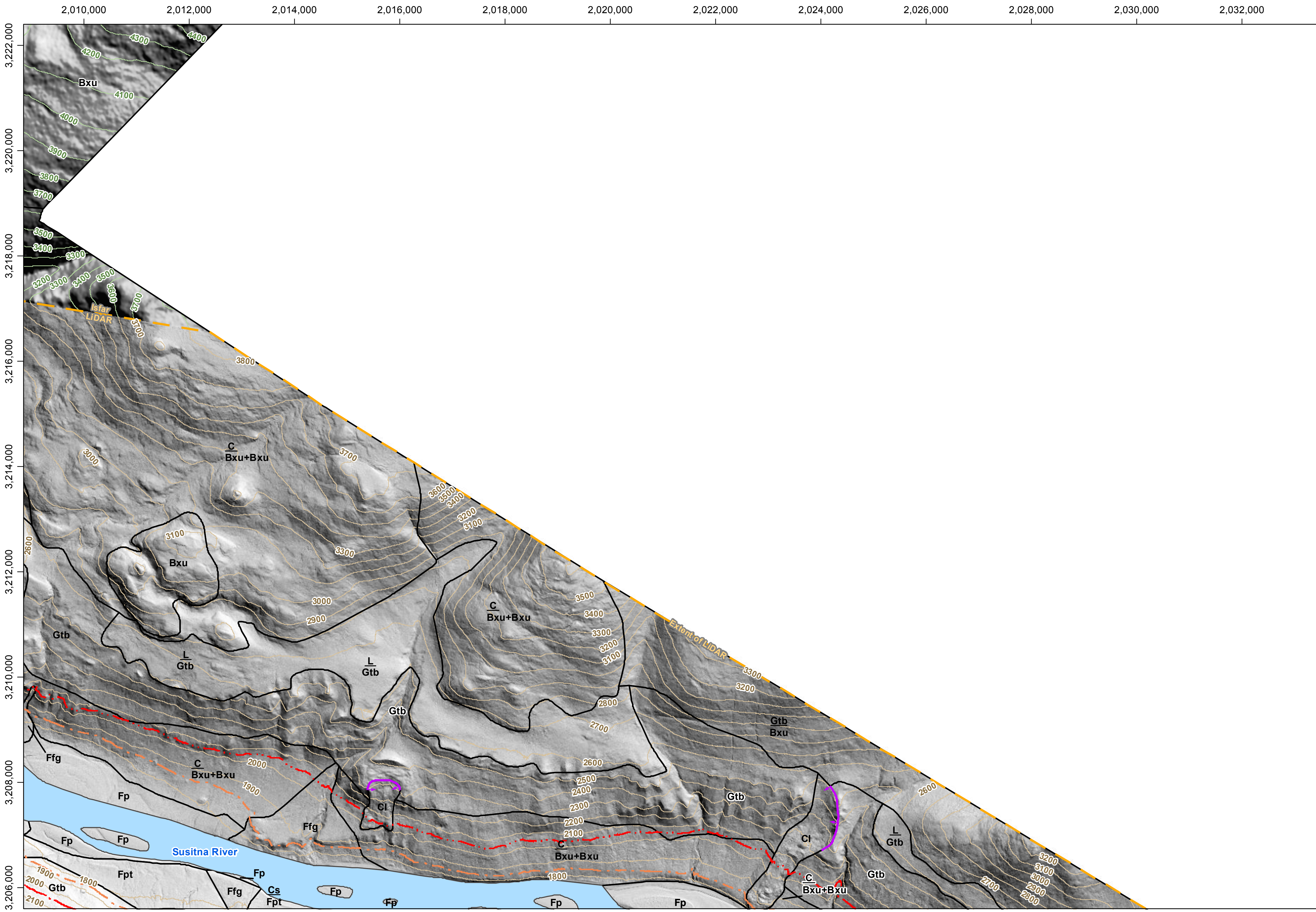


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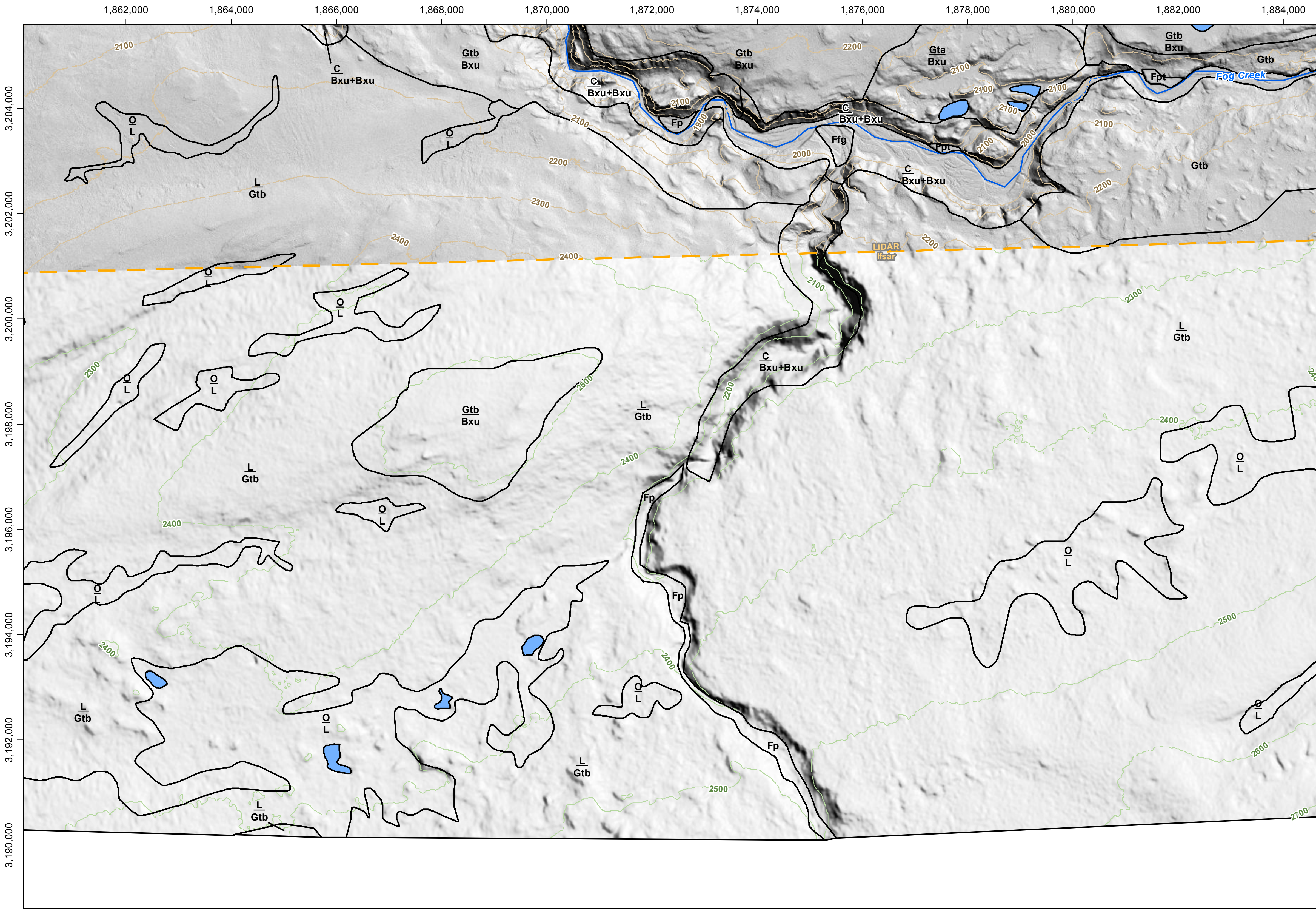


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River

Slide Scar

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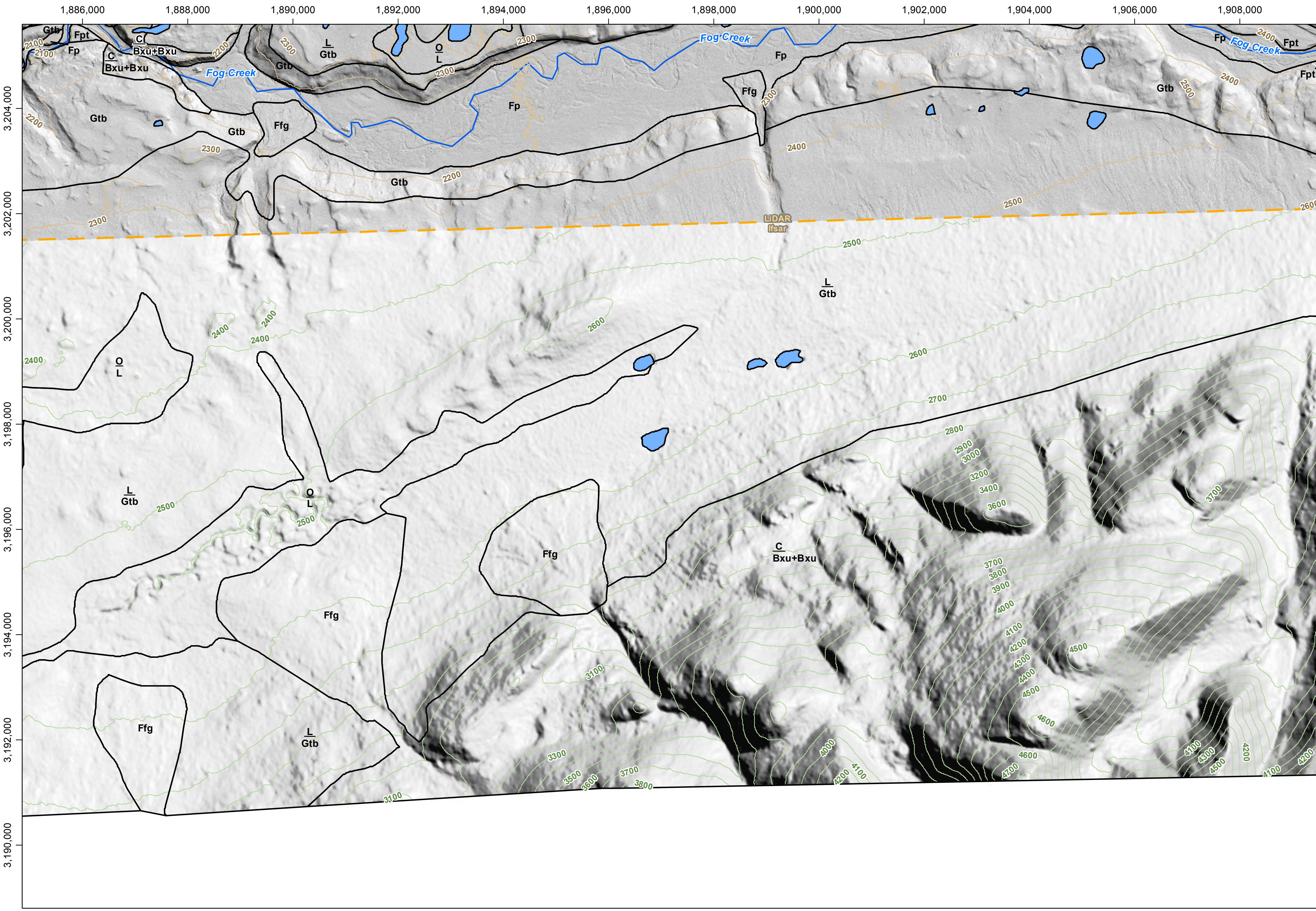


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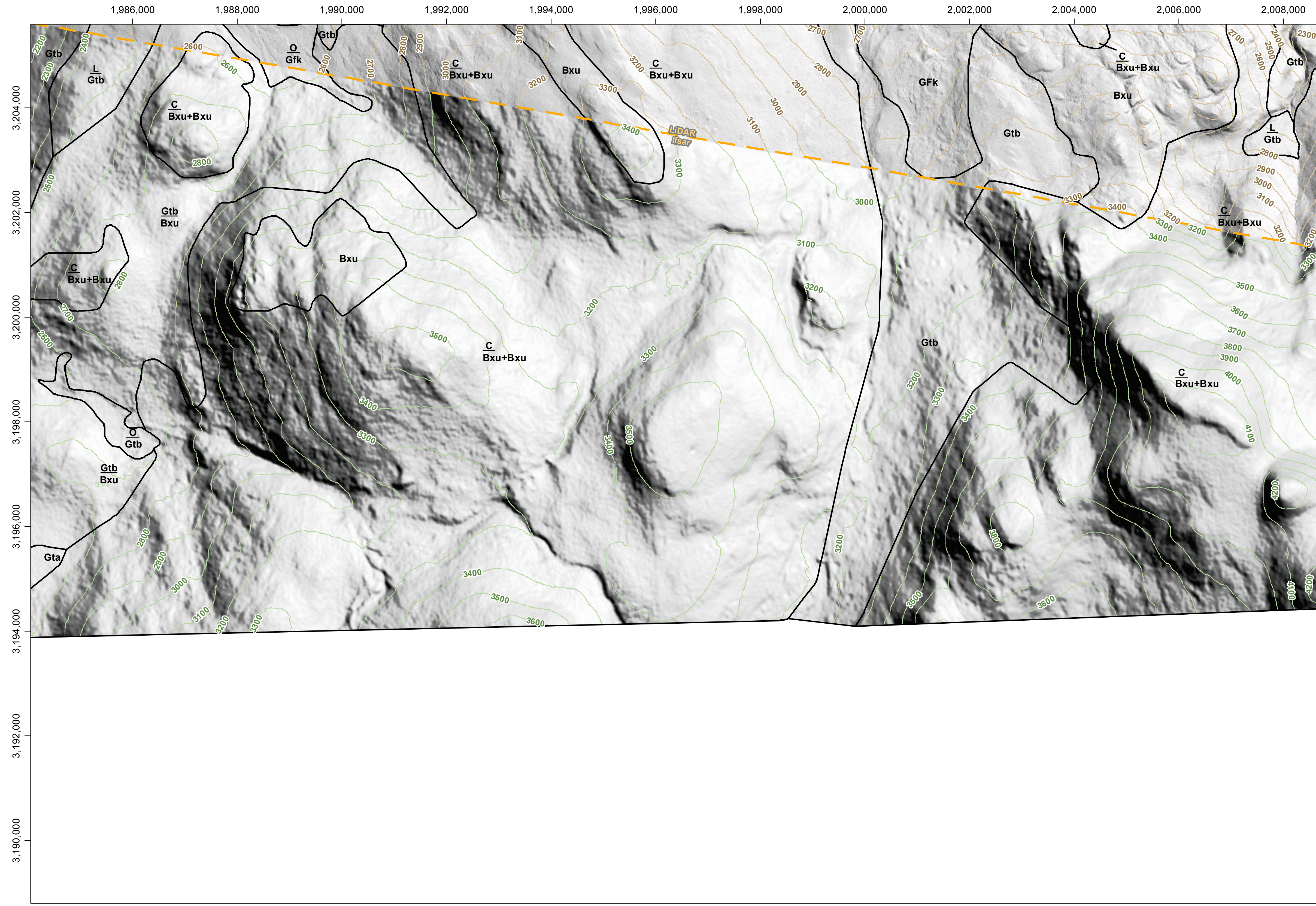


## Miscellaneous Map Symbols

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| L | Lacustrine deposits |
| Gtb | Basal till |
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ALASKA ENERGY AUTHORITY

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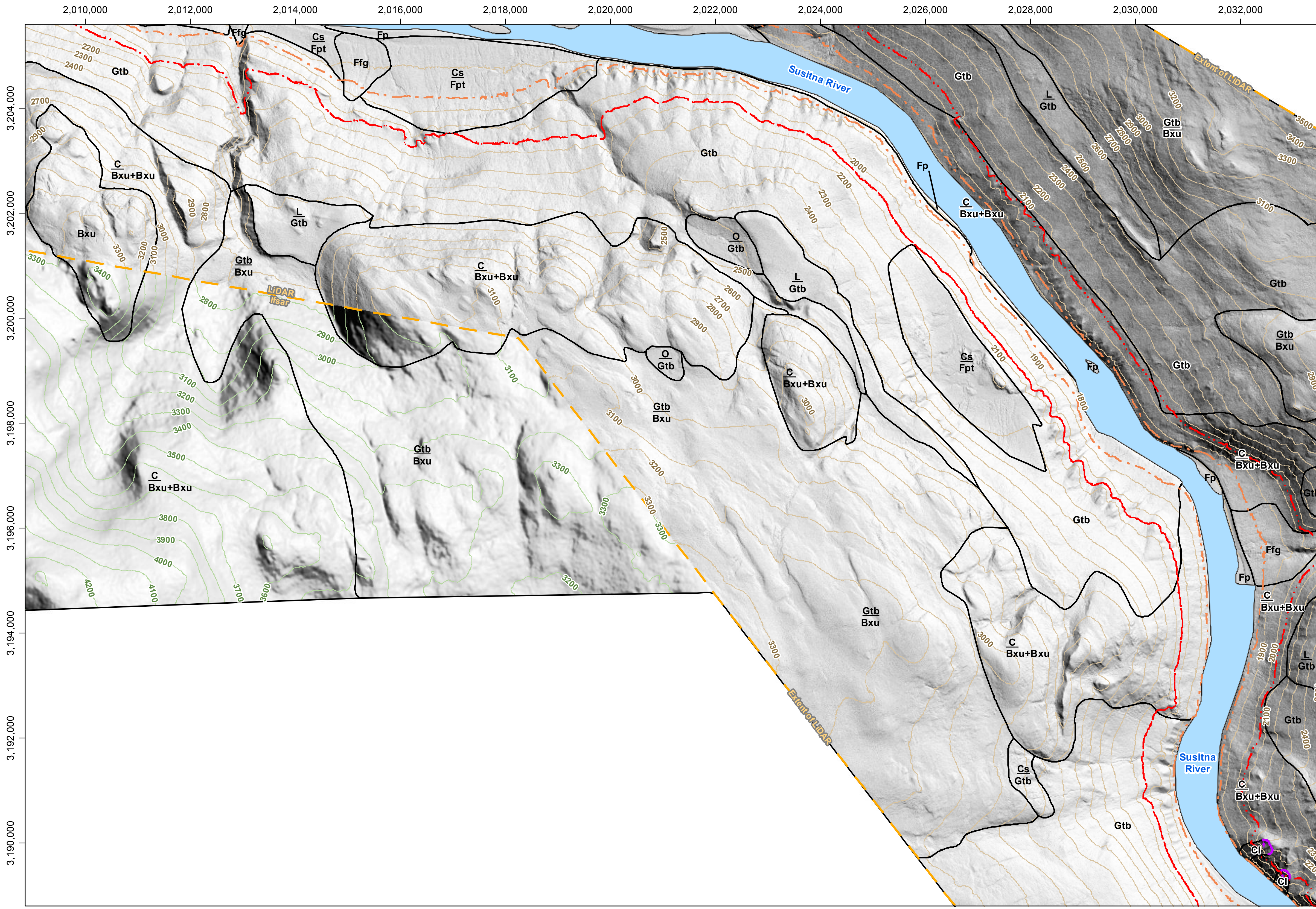


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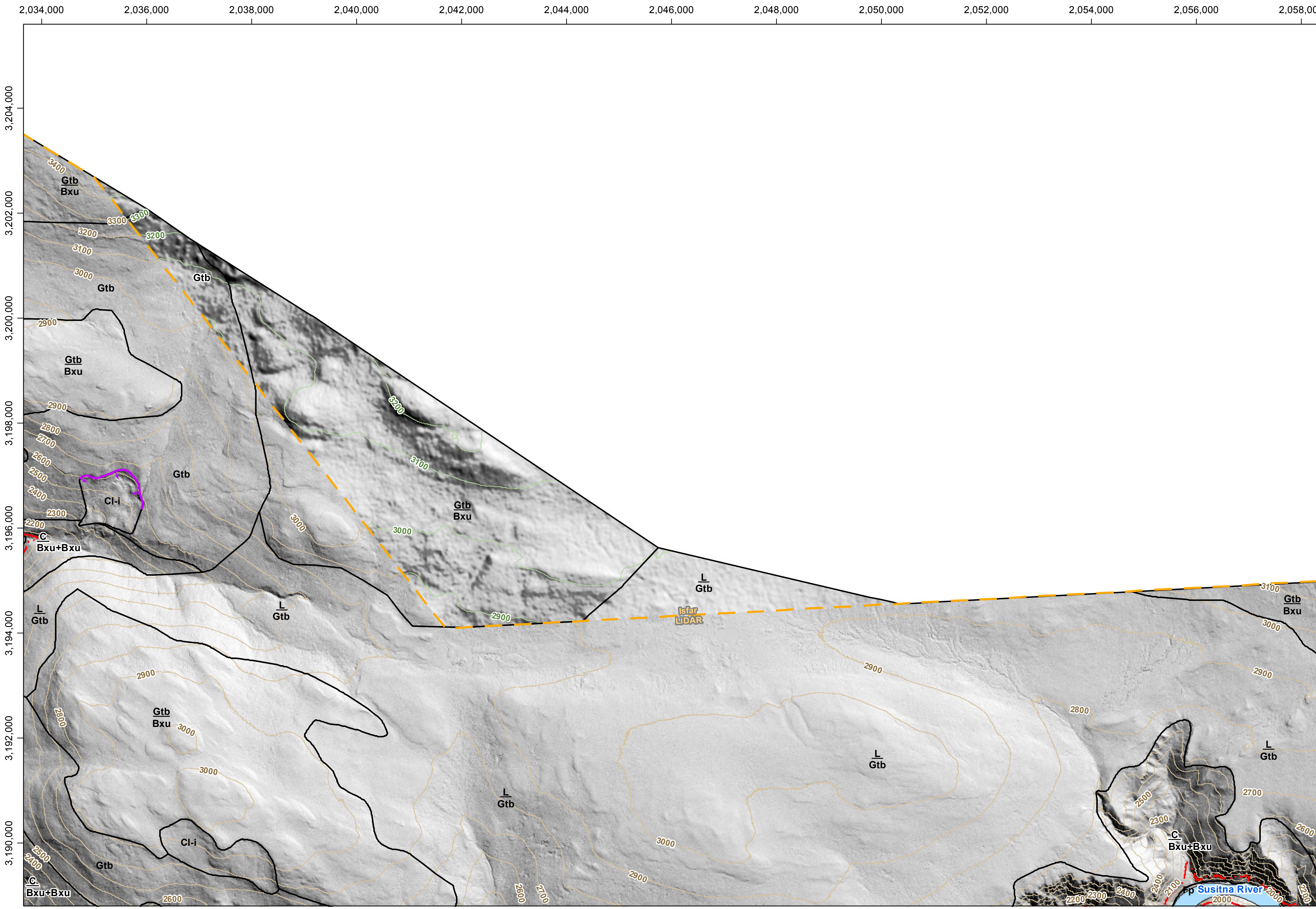


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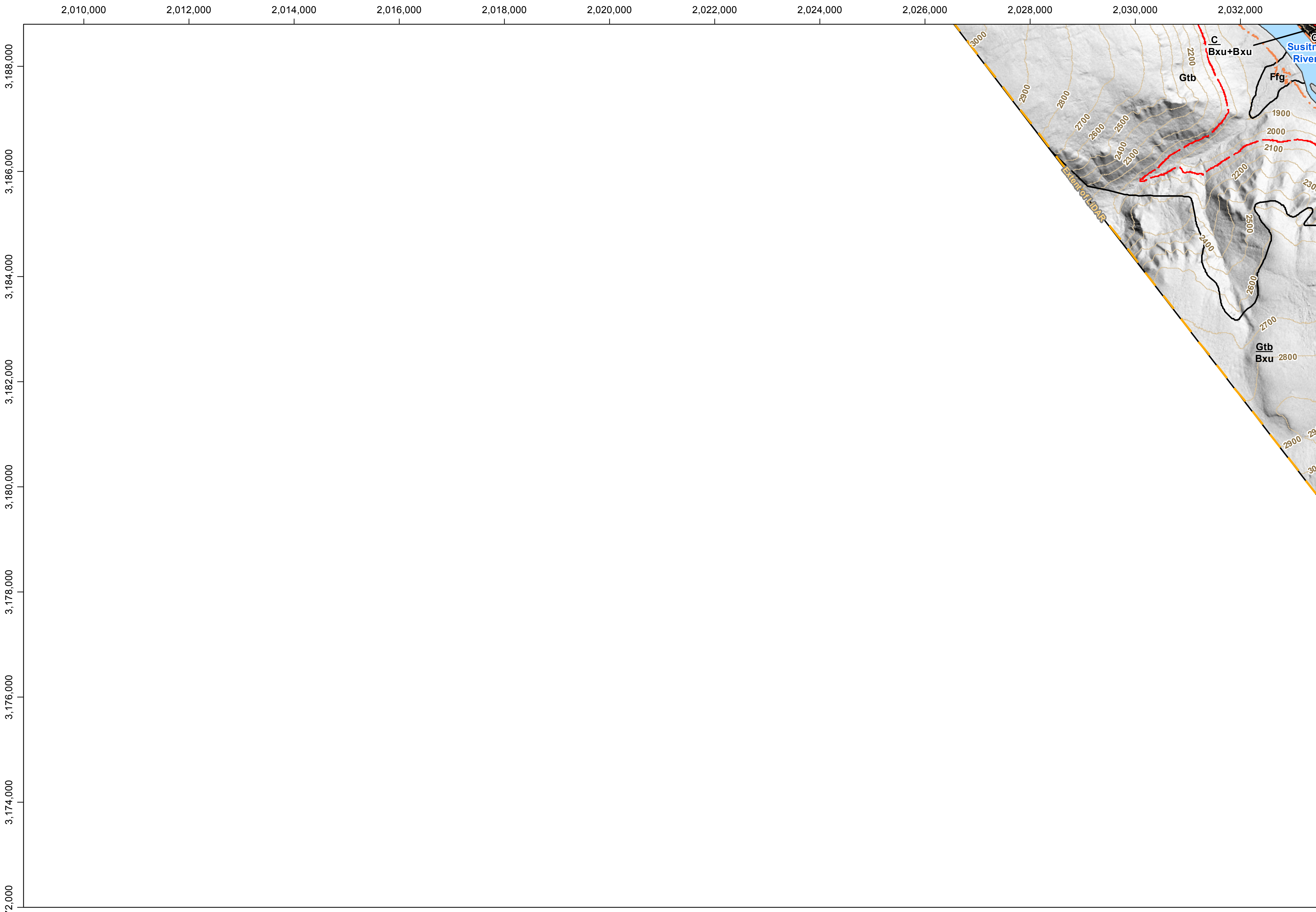


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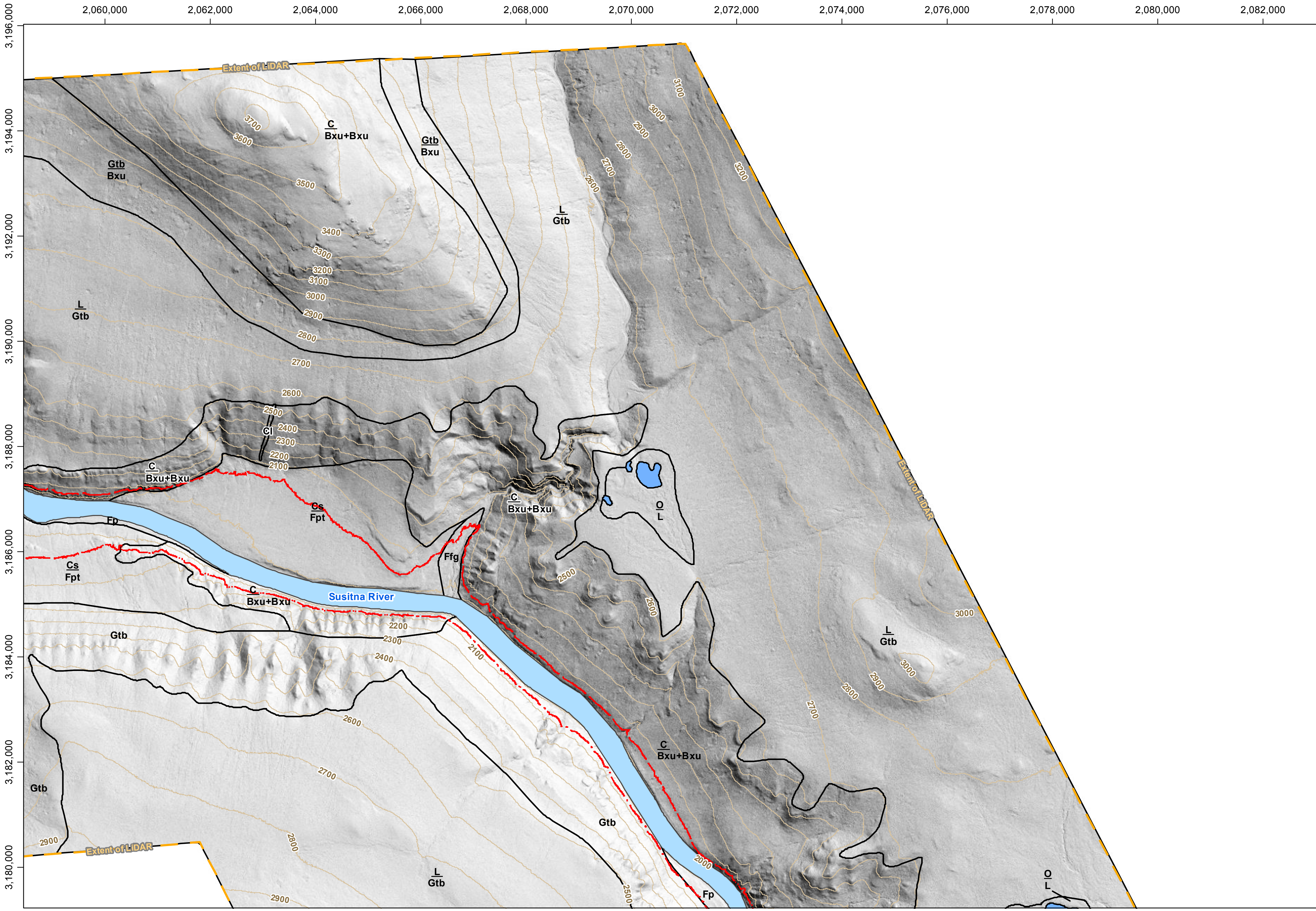


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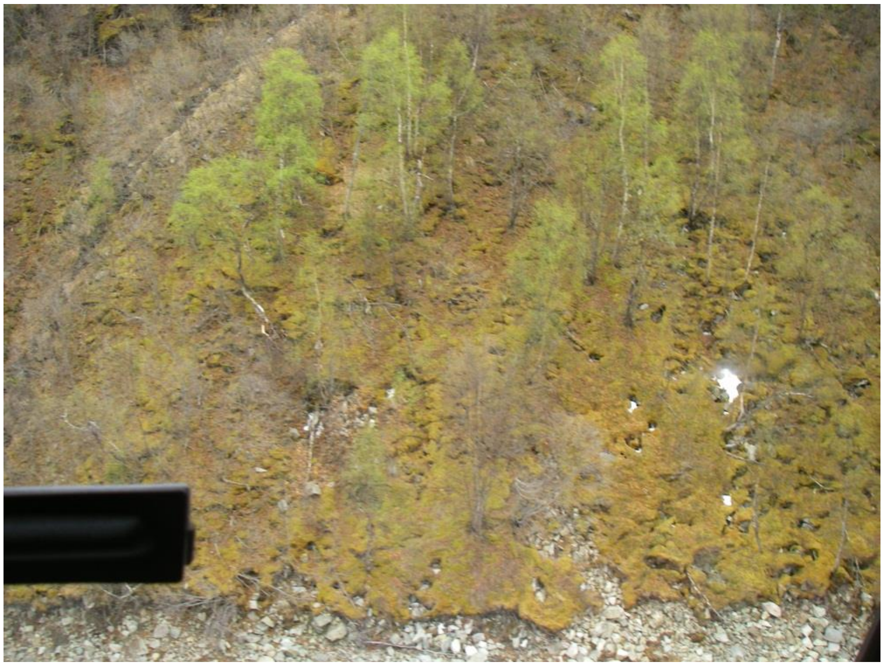
# APPENDIX A
# PHOTOGRAPHIC EXAMPLES OF TERRAIN UNITS

| **Project Title: Photographic Examples of Terrain Units** | |
|---|---|
| **PHOTO 1**<br>Organic Deposit (O)<br>[Several feet of organic material occupy a low wet area] |  |
| **PHOTO 2**<br>Colluvial Deposit (C)<br>[The colluvium on this slope, which includes a high percentage of boulders, is mantled with moss except at the base of the slope where it is exposed] |  |

| **Project Title: Photographic Examples of Terrain Units** | |
|---|---|
| **PHOTO 3**<br>Active Landslide (Cl)<br>[Recent landslide located on the north side of the Susitna River] |  |
| **PHOTO 4**<br>Inactive Landslide (Cl-i)<br>[This slope is mantled with landslide debris that has reforested and appears to have stabilized except for the gray un-vegetated zones along the scarp at the crest of the slope] |  |

**Project Title: Photographic Examples of Terrain Units**

**PHOTO 5**

Solifluction Deposit (Cs)

[Solifluction results in subtle lobes on low angle slopes]

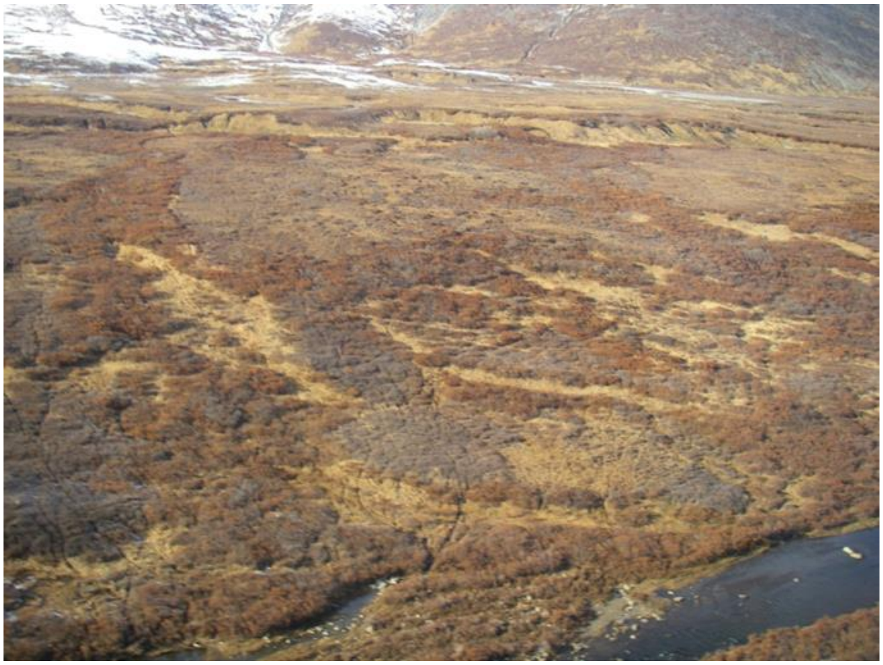


**PHOTO 6**

Granular Alluvial Fan (Ffg)

[Note the fan-shaped terrain at center of photograph with a creek at the apex of the fan]

| Project Title: Photographic Examples of Terrain Units | |
|---|---|
| **PHOTO 7**<br>Floodplain (Fp)<br>[The photo shows a mid-channel floodplain deposit with coarse sediments ranging from sand to boulders] |  |
| **PHOTO 8**<br>Ablation Till (Gta)<br>[The ablation till forms hummocky terrain with irregular lakes and ponds in the low areas] |  |

**Project Title: Photographic Examples of Terrain Units**

| | |
|---|---|
| **PHOTO 9**<br>Lacustrine Deposits (L)<br>[Lacustrine deposits are exposed at the top of the slope, above the slide debris, in a tributary valley to Watana Creek] |  |
| **PHOTO 10**<br>Basal Till (Gtb)<br>[The photograph shows a small slide that exposes basal till mantling bedrock on a moderate slope. The exposed material has a wide range of particle sizes including boulders that are visible in the photograph] |  |

**Project Title: Photographic Examples of Terrain Units**

<table>
<tr><td>

**PHOTO 11**

Bedrock (undifferentiated) (Bxu)

[The photograph shows dioritic bedrock with steep jointing outcropping along the Susitna River]

</td><td></td></tr>
<tr><td>

**PHOTO 12**

Slopes over the mid-reaches of the proposed reservoir are typically mantled by basal till (Gtb) except along the active channel where floodplain (Fp) deposits predominate.

</td><td></td></tr>
</table>