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LONG-TERM DEVELOPMENT OF VEGETATION COMMUNITIES AT FOUR PAST-PRODUCING B.C. MINE-SITES

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Abstract

Few long-term (> 15 years) studies of vegetation communities on past-producing mine-sites have been carried out. Considerable effort goes into test-plot experiments to design re-vegetation programs prior to termination of production but usually little monitoring has been done after mining operations cease. In addition, little is known from test plots of the long-term effect of competitive interactions between seeded/planted species themselves and between seeded/planted species and invading native species.

The present study revisited and repeated some of the scientific studies carried out at four mine-sites during the period 1973-1978 by Ministry of Energy, Mines & Petroleum Resources (MEMPR) and/or University of British Columbia. (UBC) On-site studies carried out during the 1993 field season included soil sampling and visual measurements of plant species and population density. Mine-sites were in different biogeoclimatic locations and at each mine, sample sites varied by type of waste material. Results show an expected variation between mine-sites under different biogeoclimatic regimes and less predictable development of the plant community over a 17-19 year period at individual mine-sites.

This study was carried out by the author as part of an M.Sc. thesis project studying natural regeneration of vegetation at past-producing mine-sites.

INTRODUCTION

Following amendments to the provincial Mines Act in 1969, rehabilitation of areas disturbed by mining in B.C. to a productive land-use has been a component of the plan for de-commissioning of mines. The objective is to promote a healthy vegetation community, compatible with the surrounding natural vegetation which in time will satisfy a land-use objective, be it rangeland, recreational use or wild-life habitat, as cost-effectively as possible.

Revegetation of mine waste material is pursued using a variety of techniques but the most common involves various degrees of ground preparation followed by seeding/fertilising to

promote a mix of grass and legume species with the short term objective of controlling erosion, limiting the invasion of weedy species, improved visual appearance and the long term objective of initiating nutrient cycling to improve "soil" conditions and allow succession of a natural vegetation community to evolve. The technique(s) to be used are chosen from the results of test plots using different permutations of ground preparation, seed mix, fertiliser type and application timing and rates. However, test plots provide little in the way of predicting the evolution of the vegetation community. Neither the influence of intra-specific and interspecific competition of seeded species nor the effects of invasion by native species can be predicted. Usually monitoring of re-vegetation stops a few years after after the final fertiliser application unless there are reasons for further monitoring e.g. water quality. Thus, few studies exist describing the development of the vegetation community over a long period.

The objective of this study was to assess the association of plants growing on a particular site in order to define any change in the plant community over a 15-20 year period without anthropogenic manipulation of the mine-sites. Assessments were conducted on sites which had ceased production before 1969 and re-colonised naturally and others which had been revegetated according to the post-1969 regulations.

METHODS

It was important to select mines both in different biogeoclimatic zones and where baseline data were available such that the span between the baseline measurements and the current data was at least 15 years to allow for a statistically meaningful change to take place. It was important that each site had been undisturbed for this period to allow natural cycles to develop with no fertilising, irrigation or other anthropogenic impacts such as recreation activities. The mine-sites chosen included:

Coal Creek Collieries (coking coal)
Cumberland No.4 Colliery (steam coal)
Pinchi Lake (Mercury)
Texada Iron Mines (Magnetite, copper)

Table 1: Biophysical features of the mine-sites

	COAL CREEK	CUMBERLAND No. 4 MINE	PINCHI LAKE	TEXADA IRON
Biogeoclimatic zone	ICH dw	CWH mm	SBS mh	CDF mm
Elevation (m)	1020	160	715	75
Aspect	E-W	W	S	S
Area disturbed (ha)	30	15	82	130
Years undisturbed	35, 50	>70	14	>30
Total precipitation	1128	1570	495	875
Max. distance to seed source (m)	150	150	300	200

The sites at Coal Creek, Cumberland No.4 and Texada Iron have all reclaimed! miturally over different periods of time while Pinchi Lake has been actively reclaimed by the mining company.

Baseline studies have been carried out by mining company personnel, UBC Soil Science Department or Faculty of Forestry or MEMPR between 1973 and 1978. Field work for the current study was carried out by the author during 1993. Sample plots from the original studies were relocated as accurately as possible based on finding the original marking stakes, maps from previous reports or descriptions from previous authors where possible. Assessments of species and percentage cover were estimated visually for a 5mx5m quadrat. The 25 m^2 quadrat was chosen as the maximum size of plot that could be assessed in open terrain and one which would give the best qualitative snapshot of the vegetative community established on that type of disturbed site. Although this method is subjective and both less precise and accurate than other accepted methods it is internally consistent. Since the purpose of the study was to compare plant associations rather than the absolute change in species composition and population density, no quantitative comparison with previous surveys has been made and all data is presented in a

qualitative rather than quantitative way. The position of all sample plots assessed in 1993 has been marked by a small wooden stake with an aluminum tag and geo-referenced in UTM coordinates either from maps or a portable GPS unit. An ecological site description following the MEMPR "Reclamation Site Inventory" was completed for each quadrat.

Figure 1 shows a comparison of average monthly temperatures and precipitation for the sites.

RESULTS

Coal Creek Collieries

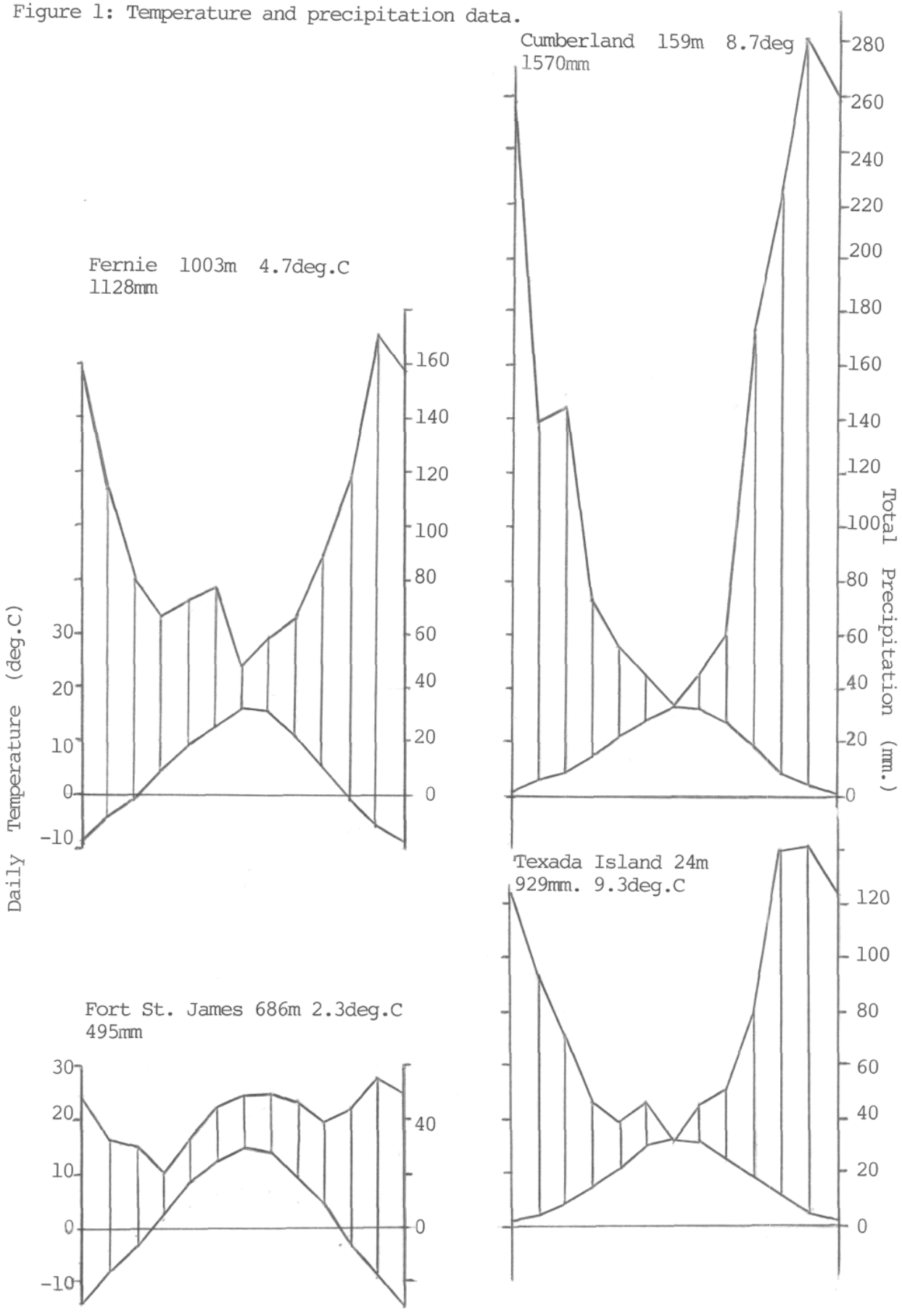
The narrow Coal Creek valley lies south of Fernie, oriented east-west. Coal has been exploited from underground workings by two mines, Coal Creek Colliery and Elk River Colliery. The Coal Creek plant and town-site occupied the eastern end of the valley from 1928-1943 and Elk River operated from 1946-1958 on the south side of the valley to the west, including a washing plant. The disturbed area is about 30 ha. No formal revegetation has been recorded but natural revegetation is complete, dominated by cotton wood with snowberry and weedy herbs. Some shifting of spoil piles has been carried out primarily for recreation purposes but the site is relatively undisturbed and evidence of mining activity can be seen in unvegetated slopes and unfamiliar contours. The 1977 study carried out by the UBC Soil Science Department (Lavkulich et al, 1978) characterised 3 types of spoil material from the Coal Creek valley.

1. Settling pond material from the Elk River Colliery washing plant. Although this site was re-sampled, it has not remained undisturbed having been used for moto-cross and is not used for comparison purposes.
2. An elevated grassland embankment used by the Coal Creek Colliery railway which at surface consists largely of ash, probably from the steam plant. The colliery closed in 1943.
3. A well forested site, the remains of a waste rock dump constructed before 1943 but since largely removed for fill and levelled.

Grassland site

In 1977 the plant cover was limited to more drought resistant weedy herb species and grasses. Bull thistle, bladder campion, sweet clover, fireweed and rabbit brush were common herbs and red top and fescue were dominant grasses. Problems of water stress were evident. In 1993 both aspen and cottonwood are established. The dominant shrub is snowberry with saskatoon, douglas

Figure 1: Temperature and precipitation data.



maple and choke cherry. The main weedy herbs are fringed sage, fireweed, bull thistle and vetch. Dominant grasses are timothy, bluegrass and wild rye.

Forested site

This site could not be located exactly from the 1977 photographs. Some trees may have been felled by campers who use part of the site. In 1977 the site had lush vegetation with dominant species being aspen, cottonwood, sweet clover, red fescue and timothy. By 1993 the dominant tree species was cottonwood (up to 25m; dbh 37cm) although aspen and douglas fir individuals are present less than 50m away. Snowberry is the dominant shrub, not encountered in 1977. The only grasses present are bluegrass and wild rye. Substrate quality is being improved by cycling of nutrients by leaf litter and soil structure is being improved by the presence of soil macrofauna.

Cumberland No.4 colliery

The Cumberland No.4 mine was an underground mine accessed by an inclined shaft collared at the base of the bluff at the eastern end of Lake Comox, 20Om north of the inflow of Coal Creek. The site examined lies on the dump constructed of run-of-mine waste delivered by train from the incline shaft. The waste was spread in linear piles close to the incline collar by using an advancing track on top of the dump 2-6m high. The dumps now occupy an area of about 10 ha. and form the shore of the enlarged Lake Cornox. The area is now covered with a second growth stand dominated by Hemlock of dbh 37-75cm with an open understorey. The exact age of the dumps is unknown but they were abandoned before 1924 and all regeneration of vegetation is entirely natural (J. Weir: personal communication). Seed dispersal across the dump has been aided by the height of the bluff and the dump has remained unmarked by moto-cross riders because of the steep side to the dump adjacent to the road.

The spoil area was studied previously in 1973 (Errington, 1975) with a transect of 17 contiguous 4mx4m quadrats running westward from the road and perpendicular to the waste piles. The 1973 transect was relocated to within 50m and was repeated using five 5mx5m quadrats spread out over the same distance. Any changes in vegetation were expected to be incremental since the vegetation was already well established in 1973. Light decreases away from the road and the last quadrat was illuminated only by light from the canopy above (80% closure), Soils are well

drained and dark coloured with a significant proportion of coal fragments (pH=5, n=3). There is no change in the predominantly hemlock canopy. However, total ground cover was as low as 36% in the 1973 survey and is now 100%, (except for the occasional footpath), the increase in cover being from mosses. Twinflower and huckleberry are still the co-dominant shrubs but their abundance decreases away from the road and on the last quadrat salal is dominant, followed by Oregon grape. Rattlesnake plantain and wall lettuce are still the dominant herbs.

Pinchi Lake

The Pinchi Lake mercury mine operated during World War 2 and later from 1968-1975 as an underground and open-pit operation. The mine has since been actively reclaimed while under care and maintenance status and current vegetation is a dense sward of alfalfa on waste rock and grasses and clover on the tailings impoundment (Gardiner et al, 1978). Revegetation has been carried out by helicopter seeding and fertilising in the spring of 1978 and 1979. The total site disturbance is 82 ha. of which 24 ha. is occupied by the tailings impoundment, including dykes and 25 ha. by waste dumps. The tailings are alkaline (pH=8, n=25) as is the pond water (pH=8.6). Extensive reclamation research work has been carried out on the spoil material to test various reclamation techniques before operations ceased. Shrubs and trees have been planted and monitoring of vegetation has been documented in annual reports. Test plots of conifer and shrub seedlings were established in the north-east corner of the tailings pond. In addition an assessment of invasion of native shrubs on to test plots was carried out in 1977 (Gardiner and Stathers, 1981). In 1978 a survey by MEMPR assessed vegetation on all the disturbed sites (MEMPR, 1978a), however only the sampling plots on the tailings pond could be reliably relocated and thus the 1993 study focusses on the tailings pond.

The 1978 MEMPR survey took place in summer after spring seeding with a mix of alfalfa 30%, alsike clover 20%, Creeping red fescue 25%, Canada bluegrass 15% and red top 10% accompanied by N13:P16:K10 fertiliser. A north-easterly transect of 6 plots was sampled across the pond from the wet area at the edge to the drier area near the tailings inflow. In addition several of the pond testplots were sampled. Legumes had established poorly and native alkali grasses grew vigorously in all plots initially before seeded grasses could become established and seeded grasses required maintenance fertiliser in 1979 to maintain vigour. When the maintenance

fertiliser was discontinued after 1979, grasses died back allowing legumes to spread. Native woody species including cottonwood and willow grew on the inside and outside slopes of the impoundment dykes and two permanent areas of open water occupying about 4ha. had formed. By 1993 the vegetative cover is 100%. On the impoundment dykes alfalfa is dominant, however, on the pond alsike clover and fescue are co-dominant and in 5 out of 6 plots comprise at least 80% of cover. In the other plot bluegrass and foxtail barley constitute 50% of the cover. Alfalfa occurs on all sites but is only measurable in two. Alkali grass is now confined to the south and east edges of the pond where fine particle size creates seasonally inundated patches.

Since 1980 native woody species have invaded the tailings pond. Willow is easily the dominant shrub and is browsed by mule deer at the pond edges. Cottonwood, also browsed mainly at the perimeter of the pond, occurs frequently all over the pond while birch and spruce individuals occur mainly in the north-east corner. However the willow and cottonwood are not yet tall enough to provide enough refuge to allow large wildlife to cross the tailings pond. Alder do not occur in natural vegetation around the pond and so N-fixing species are limited to alsike clover. In the reclamation test plots lodgepole pine and spruce planted as 1-0 seedlings in 1972 and fertilised have attained 6m in height, while douglas fir has perished. Of the 300 lodgepole pine seedlings planted on the pond in 1972 only a few stunted individuals survive owing to low nutrient capital and alkalinity.

Texada Iron Mine

Texada Iron Mines operated principally from 1952-1976. Production was from 4 small open-pits from 1952-1964 and thereafter continued underground until termination of production in 1976. A total of 130 ha. of land has been disturbed but little of it since 1964. The orebody is a magnetite skarn type with a monzonite intrusive intruding Quatsino limestones overlain by andesitic volcanic flows. The package has been intruded by felspar porphyry dykes. The mine complex is on a steep south facing rocky slope rising from sea level to 250m with a narrow beach. Tailings were dumped into the sea and so the only waste material is 16Mt of waste rock terraced into 16m(50ft) benches with slopes at the natural angle of repose. In addition, dense waste rock has been used for creating stockpile areas and dock facilities.

All revegetation reflects natural regeneration over 25-30 years. Vegetation is sparse, mainly douglas fir on exposed dry sites and alder where moisture is less limiting. The mine property on the plateau to the north is now active as a limestone quarry and some areas of the iron mine are used as storage for limestone product and in addition dump material from the iron mine is occasionally marketed as rip-rap or aggregate. Two previous surveys have assessed the plant community; a 1976 UBC Soil Science Department study (Lavkulich et al, 1976) focussed on characterisation of the spoil materials and a 1978 MEMPR study (MEMPR, 1978b) established vegetation assessment plots. The 1993 work located the marker stakes from 5 out of 7 of the 1978 sites and 2 more were added.

The alkalinity of the waste rock (pH=8, n=16), compaction, limiting moisture and nitrogen make it a difficult site for recolonisation. In addition magnetite, crystalline limestone and silicified monzonite are highly resistant to weathering with only unsilicified volcanics having weathered to any extent. In general terms the vegetation has developed little in 15 years since 1978. Douglas fir occurs most frequently but is sparse and often has a "skirted" appearance from heavy browsing. However, douglas fir described as 2m in 1978 is now 10m tall and cone bearing. Cedar are very heavily browsed and arbutus have not propogated beyond isolated individual seedlings away from the arbutus stand at the western end of the mine-site. Herbs are typical weedy species found on dry sites. Much of the bench tops have been compacted for haulage purposes and the only species occurring consistently is poverty oatgrass. The site where significant vegetation is found and a nutrient cycle has been initiated is site 6 where alder has seeded from nearby on to a dump of uncompacted intrusive and volcanics. Weathering of waste material has occurred, pH has been reduced to 7 and measurable organic matter is present including the presence of soil macrofauna. The importance of micro-climate is shown by small douglas fir seedlings growing in the shelter of small rocks where fines and moisture have accumulated.

CONCLUSIONS

Observations at the 3 unreclaimed sites confirm the expected variation in natural regeneration based on biogeoclimatic factors. Although the sites are similar in size of opening in terms of distance from a natural seed source, the state of rehabilitation of each site is totally different.

At Cumberland No.4 mine, classic alder-hemlock succession has created a reasonably productive second growth forest cover in 75 years with conifer seed dispersal aided by local topography. The only recent development of vegetation is the increase in moss understorey leading to a hemlock-moss association. Texada Iron, although less than 50 km. from Cumberland No.4 mine is in a totally different biogeoclimatic regime and vegetation has generally changed little since 1978. This site illustrates the importance of rock weathering rates on revegetation and the influence of chemical alteration during ore-forming processes. Natural vegetation will change very slowly on the dry, exposed sites where the substrate material is resistant to weathering. The Coal Creek site, colonised by cottonwood rather than alder 50 years ago, is still nutrient limited, favouring weedy species, although improvement of the substrate since 1976 is evident in islands of "forested" type waste rock material. In time conifers will propogate to form mixed stands on these sites and increased shade will limit weedy species. Other open sites will remain dominated by weedy species with little improvement in substrate nutrient capital until nutrient cycling is initiated.

At Pinchi Lake, reclamation has been very successful in establishing and sustaining alfalfa on waste rock dump sites and a grass/clover cover on the tailings material. This is improving the N capital of the substrate and at the same time keeping out weedy species and providing a part of the diet for wildlife. Since 1978, the thick alfalfa sward has so far resisted invasion by trees or shrubs, but willow and cottonwood have colonised the grass/alsike clover cover on the tailings pond, providing forage for ungulates. Experiments on test strips clearly show that an extra annual application of maintenance fertiliser in 1980 would have inhibited invasion of native trees and shrubs for at least 13 years by increasing the vigour of seeded grasses.

REFERENCES

1. Lavkulich, L.M. et al, 1978, "Reclamation of abandoned mine spoils in British Columbia, 1977-1978." Dept. of Soil Science, University of British Columbia, 178p.
2. Errington, I.E., 1975, "Natural revegetation of disturbed sites in British Columbia" Dept. of Forestry, University of British Columbia, Ph.D. thesis, 145p.
3. Ministry of Mines & Petroleum Resources, 1978a, "Vegetation assessment at Pinchi Lake Mine", unpublished report, 24p

4. Gardiner, R.T. et al, 1981, "Cominco Ltd: Pinchi Lake operations, Annual reclamation report for 1980",36p

5.Gardiner, R.T, and Stathers, I.E., 1978, "Mined-land reclamation at Cominco Ltd. Pinchi Lake Operations."

6. Lavkulich, L.M. et al, 1976, "Pedological inventory of three sulphide mine arras in British Columbia.", Dept. of Soil Science, University of British Columbia, 183p.

7. Ministry of Mines & Petroleum Resources, 1978b, "Vegetation assessment at eight South Coast mines. " unpublished report, 10Op

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