JLC * Sites and Civil Engineering

Revisit and Update Works by Site Study Group & Utility Group

@ISG10
T. Matsuda KEK/IPNS

(*) Now GLC
Candidate Sites for JLC

Site Study Group
(Sept. 2001 – March 2003)

Two Categories:

(A) 8 Areas of Uniform Bedrock:
   (Yellow No.)
(B) 4 Areas of Scientific City or National Project:
   (Blue Characters)
### Table 6.3: Major characteristics and issues of 14 representative routes in 8 (good geology) and 4 (research and development bases) regions.

<table>
<thead>
<tr>
<th>n</th>
<th>site</th>
<th>L (km)</th>
<th>geology</th>
<th>geography</th>
<th>altitude (m)</th>
<th>depth (m)</th>
<th>power (KV(MW))</th>
<th>T (°C)</th>
<th>major issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hidaka</td>
<td>28</td>
<td>granite, hornfels</td>
<td>base of mountains</td>
<td>270</td>
<td>38-499</td>
<td>187(526)</td>
<td>7</td>
<td>power supply capacity,Route274, tunneling in alluvial valley,snow(2m)</td>
</tr>
<tr>
<td>2</td>
<td>Kitakami</td>
<td>31</td>
<td>granite</td>
<td>hilly terrain</td>
<td>100</td>
<td>80-600</td>
<td>275(746)</td>
<td>10</td>
<td>power flow,quarry,no city</td>
</tr>
<tr>
<td>3</td>
<td>Murakami</td>
<td>30</td>
<td>granite</td>
<td>highland</td>
<td>−5 ~ 70</td>
<td>36-563</td>
<td>154(154)</td>
<td>14</td>
<td>power supply capacity,snow(1m),old mines, mylonite region,quarry ,no city,hot spring</td>
</tr>
<tr>
<td>4</td>
<td>Abukuma</td>
<td>36</td>
<td>granite</td>
<td>highland</td>
<td>390</td>
<td>30-300</td>
<td>275(962)</td>
<td>11</td>
<td>power flow,golden eagle,quarry</td>
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<tr>
<td>5</td>
<td>Kita-Ibaraki</td>
<td>30</td>
<td>granite</td>
<td>highland</td>
<td>210 ~ 310</td>
<td>40-330</td>
<td>275(1138)</td>
<td>13</td>
<td>power flow,natural park,quarry</td>
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<tr>
<td>6</td>
<td>Aichi-Gifu</td>
<td>22</td>
<td>granite</td>
<td>highland</td>
<td>20 ~ 265</td>
<td>20-200</td>
<td>500(2788)</td>
<td>15</td>
<td>highway,semi-national park,quarry, hot spring</td>
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<tr>
<td>7</td>
<td>Takamatsu</td>
<td>30</td>
<td>granite</td>
<td>base of mountains</td>
<td>100 ~ 200</td>
<td>50-370</td>
<td>500(2788)</td>
<td>15</td>
<td>active faults(3 km)</td>
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<tr>
<td>8</td>
<td>Hiroshima</td>
<td>29</td>
<td>granite</td>
<td>hilly terrain</td>
<td>250 ~ 300</td>
<td>40-450</td>
<td>500(1748)</td>
<td>13</td>
<td>clump of rhododendron(1 km)</td>
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<tr>
<td>9</td>
<td>Seburi</td>
<td>38</td>
<td>granite</td>
<td>hilly terrain</td>
<td>110 ~ 230</td>
<td>60-520</td>
<td>500(2788)</td>
<td>16</td>
<td>dam construction,quarry,hot spring</td>
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<td>10</td>
<td>Mutsu-Ogawara</td>
<td>22</td>
<td>andesite, agglutinate</td>
<td>base of mountains</td>
<td>70 ~ 90</td>
<td>35-220</td>
<td>154(292)</td>
<td>9</td>
<td>snow(1m),no city</td>
</tr>
<tr>
<td>11</td>
<td>Tsukuba (KEK)</td>
<td>22</td>
<td>sedimentary layers</td>
<td>plain</td>
<td>−50</td>
<td>80</td>
<td>500(1788)</td>
<td>14</td>
<td>urban area, stability, road vibration</td>
</tr>
<tr>
<td>12</td>
<td>Mt.Tsukuba (Bucyouzan)</td>
<td>31</td>
<td>granite, metamorphic</td>
<td>hilly terrain</td>
<td>40</td>
<td>30-500</td>
<td>500(1788)</td>
<td>14</td>
<td>JR Mito line,Route50,Joso tunnel, semi-national park,quarry,hot spring</td>
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<tr>
<td>13</td>
<td>Harima (Spring8)</td>
<td>30</td>
<td>ophiolite, shale etc.</td>
<td>hilly terrain</td>
<td>40</td>
<td>28-365</td>
<td>500(6712)</td>
<td>14</td>
<td>heterogeneous geology,Chikusa-river, Chizukyu line,hot spring</td>
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<tr>
<td>14</td>
<td>Okinawa</td>
<td>24</td>
<td>phyllite, sand</td>
<td>hilly terrain</td>
<td>50</td>
<td>47-326</td>
<td>(1756*)</td>
<td>22</td>
<td>power supply capacity,rare animals, no city</td>
</tr>
</tbody>
</table>

Here, n, L, altitude, depth, power and T are selected region number, total length, altitude of the tunnel, minimum/maximum depth of the tunnel, nearest power lines and annual average temperature, respectively. Major issues include the most significant items to be further investigated. Non-numbered sites are development and research bases. Bold-faced parts require careful consideration.

* This shows the total power instead of nearest power line, which is available in Okinawa as at May,2003.
### Table 6.4: Preliminary assessment of candidate sites

Note: For comprehensive evaluation, the weighting factors for the scores in this table require further studies.

<table>
<thead>
<tr>
<th>Candidate site</th>
<th>Length</th>
<th>Geology</th>
<th>Absence of large river</th>
<th>AC power</th>
<th>Climate and Cultural noise</th>
<th>Environmental impact</th>
<th>Access</th>
<th>Research infrastructure</th>
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<tbody>
<tr>
<td>Hidaka</td>
<td>⭕</td>
<td>⭕</td>
<td>⭕</td>
<td>△</td>
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<td>(SPRing-8)</td>
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<td>⭕</td>
<td>⭕</td>
<td>⭕</td>
</tr>
</tbody>
</table>

Legends:
- ⭕: Good
- ⭖: Fair
- △: shortage of water supply
- <strong>○</strong>: Excellent
- <strong>□</strong>: Good
- <strong>△</strong>: Fair

- <strong>○</strong>: > 30km without rock area (granite)
- <strong>□</strong>: Vicinity of dam, rail road, heavy traffic road, snow (> 1 m).
- <strong>○</strong>: Vicinity of large city with internat’l schools
- <strong>△</strong>: Close to J-PARC or KEK.

- <strong>○</strong>: Chikusa-river expected
- <strong>□</strong>: Vicinity of large city with internat’l schools
- <strong>○</strong>: Vicinity of large city with internat’l schools
- <strong>△</strong>: no city with 100,000 residents within 30km.
Candidate Site: Two Examples

Area of Uniform Bedrock: Abukuma Site (Route No.1)

Area of Science City: Tsukuba Site (KEK Route)
One Example:

**Abukuma Site:**

Geology: Mostly Granite.

Diolite-Gabbro.

Geography: Highland

Location: Two Hours Drvies to

North-East from KEK

Three Routes:

No.1 Route: 27km

No.3 Route: 33km (Max.50km)

(Understudy)
Abukuma Site: Geography & Geography

Abukuma No.3
Abukuma Route No.1: One Example of Tunneling Plan
(For the Standard Accelerator Layout)

Acc. Tunnel (Φ 3m): 5 TBM Machines
Klystron Tunnel (Φ 4.5m): 5 TBM Machines (4.6 - 6.1 km/TBM)
6 Inclined Access Tunnels: NATM
7 Vertical Utility Shafts (Φ 3m): By Reaming Bits
Experimental Hall (100m deep): NATM
Vertical Shaft (Φ 15m) to Experimental Hall:
Construction: About 4 Years
Reaming Bit

立坑（リーミングビット）

従3mの立坑を地上部より鉛直に施工する。立坑は大口径岩盤ポーリング後にTBM掘削完了後に行う。
まず、パイロット孔（d350mm）を、上から下にTBMで施工済みのトンネルまで掘抜き、次に抵抗のためのリーミングビットもTBM坑内にて取り付け、下から上に従3mまでの掘抜きを行う。掘削完了後、TBM坑内から撤出する。
掘削完了後、立坑上部より牽引ゴンドラ内で人力により樹脂ファイバーアリミリマルスを1m撤出に施工する。
Abukuma Route No.1: One Example of Tunneling Plan

Abukuma Root No.1

Plan View

Cross Section
Abukuma Route No.1: Civil Engineering

Construction: All Feasible.

Options (Vertical Utility Shaft v.s. Horizontal Access etc.)

Cost of Civil Engineering & Construction Time: 27 km Tunnels

$600 - 700M (Experimental Hall: 23* - 62**M$) (1$ = 100Yen)

Roughly 4 Years (or Longer for Lower Cost)

May Depend on Details of Geology and Regulations
(Safety, Radiation etc.).

(*) Φ60m, H30m, (**)Φ31, H40m (!)
Another Example: Tsukuba Site

KEK Route: Semimetal Layer (Pleistocene)
80m (> 50m) Underground
Partially Residential Area
Shield Tunnels
Three Plans: 10, 22 (& 33) km

Tsukuba Mountain Route:
Mostly Granite
Mostly Under Mountains
TBM Tunnels
Plan of 31km
KEK Route:

Motivations: (→ISG8)
KEK & Tsukuba Science City
Geology & Geography: (→ISG8)
Semimetal Layer (Pleistocene)
Underground Water (-25mGL)
Tunnel Depth: 80m (>50m)
Three Plans:
  10, 22 & 33 (*) km
  (*) preliminary
KEK Route: Geology & Geography

JLC @ KEK site
Cross section
(Plan A 22km @ - 60m SL)
**KEK 22km Route:**

- IP, Injectors & Beam Dump
  - Inside KEK.
- Dumping Rings
  - On the Surface.
- Minimum Facilities
  - On the Surface outside KEK
- Under Tsukuba City
  - → Ground Vibration
    (Culture Noise)
KEK Route: Accelerator Layout

Fig. 2

Injector and Pre-accelerator Section
- Open Cut Tunnels (~10m deep), Klystron Gallery on Top
- Slant Tunnels (10% slope)
- Accelerator Tunnels and Detector Hall (~80m deep)
- Klystron Gallery (~7m deep)

Collimator Section with XY Collimation
- 107m for Ecm = 200 GeV
- 267m for Ecm = 500 GeV

Pre-accelerator Linacs (~10m) have sparsely spaced accelerating structures to share Klystron galleries with Main Linacs.
**KEK Route: Pre-Accelerator Layout**

*Fig. 1-a*

**Injector and Pre-accelerator Section**
- Open Cut Tunnels (~10m deep) & Klystron Gallery on Top
- Shanty Tunnels (10% slope)
- Accelerator Tunnels and Detector Hall (~80m deep)
- Klystron Gallery (~7m deep)

Collimator Section w/ X-Y Collimation
- 70m for Eem = 2000MeV
- 287m for Eem = 5000MeV

Pre-accelerator Lines (-1km) have sparsely spaced accelerating structures to share Klystron galleries with Main Lines.

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*Diagram details and labels are not transcribed.*
KEK Site: Plan A (22 km)

Tunnel Layout

- Injector system up to the damping rings is on the surface (-10 m).
- Inclined (10 %) tunnels to transport 1.98 GeV electron and positron to the main linac tunnel (~ -80 m).
- Main linac tunnel (3 m ⨯) with an arc at each end at ~ -80m.
- The cross section of the main linac tunnel is “locally expanded” (3 m ⨯ 4.5 m ⨯) to accommodate the first bunch compressors and the pre-linacs are installed in the main linac tunnel.
- The main linac tunnel (of the standard cross section of 3 m ⨯) also accommodates the transport lines, the second bunch compressors.
- The klystron tunnel (4.5 m ⨯) and the main linac tunnel, which is separated by 5 m, are located diagonally so that one shaft can serve for the two tunnels in the drilling and the operation.
- In some case, the underground conjunction of two tunnels is made without shaft improving the stiffness of the soil by the freezing technique or the injection (hardening agent) method.
KEK Route: Tunnel Layout (3D)

JLC @ KEK Site (Plan A: 22km)
Tunnel Layout
KEK Route: Tunnel Layout (Shaft)

Each Shaft Serves

2-4 Shield Machines

for Acc. Tunnel &

Klystron Tunnel.
KEK Route: Base to Serve 4 Shield Machines

発進基地仮設平面図
(シールド4本同時施行時：3800平方m)
KEK 22km Route: An Example of Tunneling Plan
(Among Many Variations)

Acc. Tunnel (Φ 3m)
& Inclined Beam Transfer Tunnels:
   6 Shield Machines.
Klystron Tunnel (Φ 4.5m) : 6 Shield Machines with Two Modified
(Φ 3m → Φ 4.5m)
6 Large Shafts (Φ 15m) : Automatic Open-caisson.
Tunnel Merge without Shaft (Two Locations):
4 Utility Shaft (Φ 3m): Reverse Circulation Drill
KEK 22km Route: An Example of Tunneling Plan

Acc. Tunnel φ3m
(φ4.5m around IP to accommodate BC1 & Pre-linac)

Klystron Tunnel φ4.5m
**KEK 22km Route: An Example of Tunneling Plan**

(Many Other Options)

(*) Acc. Tunnel: Partially Φ4.5m

<table>
<thead>
<tr>
<th>Shield Machine</th>
<th>Excavation (km)</th>
<th>Shield Machine</th>
<th>Excavation (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. K1</td>
<td>5.0</td>
<td>No. A1</td>
<td>5.63 R=100m</td>
</tr>
<tr>
<td>No. K2</td>
<td>5.2+08</td>
<td>No. A2</td>
<td>4.1 Merge with K5</td>
</tr>
<tr>
<td>No. K3</td>
<td>5.2+0.8</td>
<td>No. A3</td>
<td>4.1 Merge with K6</td>
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<tr>
<td>No. K4</td>
<td>5.0</td>
<td>No. A4</td>
<td>5.63 R=100m</td>
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<td>No. K5</td>
<td>1.1 Recycle A5</td>
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<td></td>
<td>Marge with A2</td>
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<td>No. K6</td>
<td>1.1 Recycle A6</td>
<td>No. A6</td>
<td>0.7+0.8</td>
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<td>Marge with A3</td>
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<td>0.7km:Inclined Tunnel</td>
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<tr>
<td>All</td>
<td>24.2</td>
<td>All</td>
<td>22.46</td>
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</tbody>
</table>
KEK Route: Major Issues

1. Ground Vibration (Culture Noise): Measured at GL-80m (->Tauchi)
2. Long Term Stability (Drift) of Tunnels in Pleistocene Semimetal Layer.
3. Cost of Large Underground Experimental Hall: New Method?
4. Cost of Shield Tunnel in Japan:
   Still Higher Than Other Countries.
   1.5 - 2.0 x TBM.
5. "Accelerator" Partially Under Residential Areas of Tsukuba City:
6. ,,,,,,,,,,,,,,,,,,
7. Future of KEK:
KEK Route: Experimental Hall

1. City NATM: Cheep but Feasibility with High Underground Water?

2. Diaphragm Wall Method: Feasible but Expensive.

3. Whale (Dinosaur) Bone Roof Method:
   Very Interesting
   But No Real Experience Yet.
KEK Route: Experimental Hall (Diaphragm Wall)

3 x Φ50m
Experimental Hall (31mΦ x 100mL)
by Three Diaphragm Walls
KEK Route: Experimental Hall (Dinosaur Bone)

Technology in R&D Stage:
“Wakunami” Tunnel (‘01-‘05)
(R=5.0 and 6.3 m)
KEK Route: Experimental Hall (Dinosaur Bone)
KEK Route: Experimental Hall (Dinosaur Bone)
(30m x 30m x 60m)
28mH x 28W x 60mL

A-A 断面図  S=1/1,000

B-B 断面図  S=1/1,000
KEK Route: Experimental Hall (Dinosaur Bone)

Acc. & Klystron Tunnel

Water Proof Structure

Stell Tubes Filled with Concreat

Small Shaft

Concreat Lining
KEK Route: Civil Engineering

Construction:
  Tunnels and Shafts: Feasible. Many Options.
  Various Advanced Shield Technologies.
  Experimental Hall: Major Technical Issue (Dinosaurs Bone?)
  Expensive.

Cost of Civil Engineering and Construction Time: 22 km
  940 - 990M$ (Experimental Hall*: 150 – 170M$)
  About 5 Years.
  Not Much Depend on Details of Georgy.

(*)Diaphragm Wall, Φ50m.
KEK Route 33km:

Change Direction to More North-South?

At South End:
  Joban Highway
  (Better than Higashi Ohdori?)
  JR Joban Railway
  Tsuchiura City
JLC * Sites and Civil Engineering
Summary or Plan

Site Study: Proposed A Review by Outside Experts of Various Fields.
   (But When?)

Civil Engineering: Continue Case Studies for More Details.

Facility: Revision (for Consistent Estimate for X-band).
   Start Case Studies.

(*) Now GLC